

UNIVERSITY OF BRISTOL



THE ANNUAL REPORT

OF THE

Agricultural and Horticultural
Research Station

(THE NATIONAL FRUIT AND CIDER INSTITUTE)

LONG ASHTON, BRISTOL

1957

BATH :

PRINTED BY THE MENDIP PRESS LTD.

AGRICULTURAL COMMITTEE, 1957-58.

Appointed by the Ministry of Agriculture, Fisheries and Food.

A. WOODALL, Esq., 34, Weoley Hill, Selly Oak, Birmingham 29.

Appointed by the Agricultural Research Council.

PROFESSOR E. J. MASKELL, M.A., Ph.D., F.R.S., Department of Botany, Birmingham University.

G. SAMUEL, Esq., M.A., Agricultural Research Council, Cunard Building, 15, Regent Street, London, S.W.1.

Appointed by the National Fruit and Cider Institute.

CAPTAIN D. M. WILLS, C.B.E. (*Chairman*), Barley Wood, Wrington, Somerset.

C. P. NORBURY, Esq., Sherridge, near Malvern, Worcestershire.

T. N. HOBLYN, Esq., O.B.E., East Malling Research Station, near Maidstone, Kent.

E. BALL, Esq., Oldfield, Pipe and Lyde, Hereford.

GILES TUKER, Esq., Butts Green Orchards, Danbury, Essex.

T. W. BARNES, Esq., Showle Court, Yarkhill, Ledbury, Herefordshire.

T. H. MERSON, Esq., Wardway, North Petherton, Somerset.

Appointed by the Senate of the University of Bristol.

PROFESSOR H. G. H. KEARNS, O.B.E., B.Sc., Ph.D., Dip. Agric., Professor of Agricultural and Horticultural Science in the University.

PROFESSOR WILSON BAKER, M.A., D.Sc., F.R.S., Professor of Organic Chemistry in the University.

PROFESSOR J. E. HARRIS, M.A., Ph.D., F.R.S., Professor of Zoology in the University.

PROFESSOR A. MESSERVY, M.R.C.V.S., Professor of Veterinary Surgery in the University.

Appointed by the Council of the University of Bristol.

THE VICE-CHANCELLOR (SIR PHILIP MORRIS, C.B.E., M.A., LL.D.), The University, Bristol.

ANDREW HAGGARD, Esq., The Hilltop Fruit Farm, Ledbury, Herefordshire.

THE RIGHT HON. EARL WALDEGRAVE, Chewton House, Chewton Mendip, Bath.

PROFESSOR J. L. M. MORRISON, C.B.E., D.Sc., Professor of Mechanical Engineering in the University.

Appointed by the Gloucestershire County Council.

H. R. STEPHENS, Esq., M.B.E., Hortham Farm, Almondsbury, near Bristol.

Appointed by the Somerset County Council.

MAJOR W. F. Q. SHULDHAM, East Stoke House, Stoke-under-Ham, Somerset.

Appointed by the Wiltshire County Council.

O. M. PEALL, Esq., Hatfield Farm, Oare, Marlborough, Wiltshire.

Appointed by the Food Investigation Board.

R. G. TOMKINS, Esq., M.A., Ph.D., Ditton Laboratory, Larkfield, Maidstone, Kent.

Appointed by the National Association of Cider Makers.

R. N. HENLEY, Esq., Whiteways Cyder Company Ltd., Whimble, Devon.

Appointed by the Apple Juice Producers' Association of Great Britain.

V. L. S. CHARLEY, Esq., Ph.D., 40, Boxbush Road, Coleford, Gloucestershire.

Co-opted Members.

A. ESMOND ROBINSON, Esq., O.B.E., M.C., Eastfield, Flax Bourton, near Bristol.

C. E. HUDSON, Esq., C.B.E., Senior Education and Advisory Officer, Ministry of Agriculture, Fisheries and Food, Great Westminster House, Horseferry Road, London, S.W.1.

Secretary.

THE REGISTRAR AND SECRETARY OF THE UNIVERSITY,
H. C. BUTTERFIELD, M.A.

LIST OF STAFF—1957.

Long Ashton Research Station.

Director :

PROFESSOR H. G. H. KEARNS, O.B.E., B.Sc. (Lond.), Ph.D., Dip. Agric. (Cantab.).

Secretary :

A. L. LEGGETT, A.C.A.

Nutrition of Fruit Plants :

C. BOULD, M.Sc., Ph.D. (Reading).
D. G. HILL-COTTINGHAM, M.Sc. (Lond.), A.R.I.C.
E. G. BRADFELD, A.R.I.C.
G. V. C. DAVIES, B.Sc. (Bristol).
W. K. HANCOCK.
MISS A. J. KNIGHT. (*Appointed 2 September, 1957*).
P. BALE. (*Appointed 1 October, 1957*).

Pomology and Plant Breeding :

L. C. LUCKWILL, B.Sc., Ph.D. (Bristol).
D. L. ABBOTT, B.Sc. (Lond.).
R. R. WILLIAMS, B.Sc., Dip. Hort. Sci. (Bristol).
*D. WILSON, B.Sc. (Dunelm), Ph.D. (Wales). (Plant Breeder).
MISS B. A. RAKE, B.Sc. (Reading), N.D.H.
A. I. CAMPBELL, N.D.H. (Hons.).
P. S. WEAVER.
MRS. A. J. MEGENIS (née Beagles). (*Resigned 31 October, 1957*).
MISS G. NORTH-SMITH.
MISS A. TURNER.

Plant Physiology :

E. J. HEWITT, B.Sc. (Lond.), Ph.D. (Bristol), A.K.C. (*Seconded to A.R.C. Unit of Plant Nutrition*).

Chemistry :

J. T. MARTIN, B.Sc. (Birm.), Ph.D., D.Sc. (Lond.), F.R.I.C.
D. WOODCOCK, M.Sc., Ph.D. (Dunelm), F.R.I.C. (Organic Chemistry).
W. D. E. THOMAS, B.Sc., Ph.D. (Wales), F.R.I.C. (Physical Chemistry).
**E. SOMERS, M.Sc. (Leeds), Ph.D. (Bristol).
E. J. SKERRETT, Ph.D. (Bristol), A.R.I.C.
C. P. LLOYD-JONES, B.Sc. (Bristol), A.R.I.C.
D. F. DOWNING, B.Sc., Ph.D. (Bristol). (*Appointed 1 January, 1957*).
R. F. BATT.
J. A. PICKARD.
D. V. RICHMOND, B.Sc. (Lond.), Dip. Hort. Sci. (Bristol), A.R.I.C. (*Appointed 1 August, 1957*).
A. J. SIMS, A.R.I.C. (*On National Service from 1 March, 1956*).
E. A. BAKER.
D. R. CLIFFORD.
MISS P. M. JACKSON. (*Resigned 30 April, 1957*).
B. L. DAVIES.
MISS V. W. ROGERS. (*Resigned 16 August, 1957*).
MISS A. TAPSCOTT.
L. POTTER.
J. T. DAVIES.

**Postdoctorate Fellowship of the National Research Council of Canada at the Central Experimental Farm, Ottawa, from 17 October, 1957.*

***Postdoctorate Fellowship of the National Research Council of Canada at the Science Service Laboratory, London, Ontario, from 3 October, 1957.*

LIST OF STAFF—*continued.*

Entomology :

H. G. H. KEARNS, O.B.E., B.Sc. (Lond.) Ph.D., Dip. Agric., (Cantab.).
 S. H. BENNETT, B.Sc., Ph.D. (Bristol).
 N. G. MORGAN, B.Sc., Ph.D. (Bristol).
 A. STRINGER, B.Sc. (Lond.), A.R.C.S.
 C. G. L. FURMIDGE, B.Sc., Ph.D. (Nottingham), A.R.I.C. (Physical Chemistry).
 H. R. MAPOTHER, B.A., B.Sc. (Dublin).
 T. E. COBBALD, B.Sc. (Lond.), G.I.Mech.E.
 B. D. SMITH, B.Sc. (Sheffield), Ph.D. (Lond.), D.I.C. (*A.R.C. Special Grant from 1 October, 1957*).
 A. H. WILKINS.
 MISS M. P. SCADDING.
 J. H. RUSSELL.
 D. E. ALIBAND.
 MISS B. K. I. BIRD.
 MISS D. I. CONIBEAR.
 MISS P. J. HERRINGTON.

Plant Pathology :

R. W. MARSH, M.A. (Cantab.).
 R. J. W. BYRDE, B.Sc. (Hort.), Ph.D. (Reading).
 A. T. K. CORKE, B.Sc., Ph.D. (Edin.).
 R. O. SHARPLES, B.Sc. (Lond.). (*Boots Special Grant from 11 September, 1957*).
 A. H. FIELDING.
 MISS N. M. WAUGH.
 MISS M. MARLOW.
 MISS M. WALLER.

Cider and Fruit Juices :

A. POLLARD, M.Sc. (Lond.), Ph.D. (Manc.).
 G. C. WHITING, B.Sc., Ph.D. (Sheffield). (Chemistry).
 MISS M. E. KIESER, B.Sc. (Bristol), A.R.I.C. (Chemistry).
 L. F. BURROUGHS, B.Sc. (Reading), A.R.I.C. (Chemistry).
 F. W. BEECH, B.Sc. (Birm.), Ph.D. (Bristol), A.R.I.C. (Microbiology).
 C. F. TIMBERLAKE, M.Sc. (Wales), A.R.I.C. (Chemistry).
 J. G. CARR, B.Sc., Ph.D. (Bristol). (Microbiology).
 R. J. HATHWAY. (Cider-Maker).
 J. H. LLEWELLYN.
 P. E. W. RODGERS.
 R. A. COGGINS.
 MISS S. J. LOCKE. (*Resigned 17 August, 1957*).
 D. J. SISSONS.
 A. H. SPARKS.
 MRS. J. C. B. WADDINGTON, B.Sc. (Bristol). (*Resigned 31 July, 1957*).
 MISS K. GUTE, B.Sc. (Bristol). (*Appointed 22 July, 1957*).
 MRS. J. M. FIELDING. (*Resigned 2 February, 1957*).
 G. BRADSHAW. (*On National Service from 4 September, 1956*).
 MISS J. BIRD. (*Appointed 1 March, 1957*).
 MISS V. L. FOWLER. (*Appointed 16 September, 1957*).

Domestic Food Preservation :

MISS B. A. CRANG, B.Sc. (Lond.).
 MISS M. STURDY, B.Sc. (H & S.S.) (Lond.).
 MRS. J. M. BOWCOTT, B.Sc. (Reading). (*Resigned 12 July, 1957*).
 MISS G. M. FAWKES, B.Sc. (Bristol). (*Appointed 1 September, 1957*).
 MISS E. M. FILER.
 MISS P. J. DAVEY.

Willows :

K. G. STOTT, B.Sc. (Wales).
 T. W. COX. (*Appointed 9 September, 1957*).

Statistics :

G. M. CLARKE, M.A., Dip. Stat. (Oxon.)
 MISS M. E. HOLGATE, M.A. (Oxon.).
 MISS S. J. SAGE. (*Appointed 2 September, 1957*).

LIST OF STAFF—*continued.*

<i>Scientific Liaison :</i>	M. GREENWOOD, O.B.E., M.Sc. (Manc.). (Scientific Liaison Officer). G. E. CLOTHIER. (Station Guide and Meteorological Recorder).
<i>Library :</i>	MISS S. M. BERESFORD, B.Sc. (Bristol), A.L.A. (Librarian). (<i>Resigned 10 August, 1957</i>). P. R. COLEGATE. (Librarian). (<i>Appointed 18 November, 1957</i>). MISS D. A. PEARCE.
<i>Laboratory Staff :</i>	F. E. MALTBY, B.E.M. (Chief Laboratory Steward). G. KITCHINGHAM. E. W. SPEAR. R. W. COATES. R. A. GREEN.
<i>Photography :</i>	G. H. JONES, A.R.P.S. E. R. WILKINS.
<i>Plantations and Greenhouses :</i>	E. W. HOBBS, B.Sc. (Bristol), N.D.H. (Plantations Officer). S. H. LEGGE. (Marketing Officer and Recorder). E. CATLOW. (Recorder). C. S. GUNDRY, S.D.H. (Greenhouse Officer). R. M. JARRETT. (Recorder). C. W. HARPER. (Spraying Recorder). N. T. WEATHERITT, N.D.H. (Recorder). J. S. COLES, N.D.H. (Propagator and Recorder). A. J. HURDLE. (Plantations Foreman). J. G. CLARKE. (Greenhouse Foreman).
<i>Workshops and Maintenance :</i>	S. E. COLE. H. J. JONES. E. A. FRIBBINS. B. F. SHEARN. K. G. JONES. (<i>Appointed 1 October, 1957</i>). R. S. COLE. (<i>Appointed 3 October, 1957</i>).
<i>Canteen :</i>	MRS. N. M. KING. MRS. E. R. DUDDRIDGE.
<i>Administrative and Clerical Staff:</i>	R. A. MERCHANT. (Chief Clerk, Accounts). D. H. PITTMAN. (Cashier). MISS M. H. SIMPSON. (Director's Secretary). J. PACKER. (Senior Clerk). T. J. FORD. MRS. J. M. BENDALL. (<i>Appointed 1 November, 1957</i>). MRS. M. WIPPELL. MISS N. K. BULLOCK. (<i>Resigned 23 March, 1957</i>). MISS E. M. MATTHEWS. (<i>Retired 31 December, 1957</i>). MISS J. M. WALTERS. MRS. D. M. SHERBORNE. MISS M. J. HATHWAY. (<i>Resigned 12 October, 1957</i>). MISS P. CURTIS. (<i>Appointed 25 March, 1957</i>). MISS C. HALES. (<i>Appointed 10 October, 1957</i>). MISS G. M. REW. MISS P. M. HEYWARD. (<i>Appointed 1 January, 1957</i>).
<i>Outdoor and Cider House Staff with more than 20 years' service :</i>	R. JONES. (35). J. C. W. BARNES (29). W. M. HYNAM (29). F. W. HYNAM (28). K. J. ESCOTT (27).

Agricultural Research Council Unit of Plant Nutrition (Micro-Nutrients).

Honorary Director :

PROFESSOR T. WALLACE, C.B.E., M.C., D.Sc., F.R.I.C., V.M.H., F.R.S.

H. E. DAVENPORT, B.Sc. (Lond.), Ph.D. (Cantab.).
E. J. HEWITT, B.Sc. (Lond.), Ph.D. (Bristol), A.K.C. (*Seconded to Unit*).
D. J. D. NICHOLAS, B.Sc. (Lond.), Ph.D. (Bristol), A.K.C., F.R.I.C.
R. A. WEBB, B.A., D.Phil. (Oxon.).
A. H. WILLIAMS, M.A., B.Sc. (Oxon.).
H. M. STEVENS, B.Sc., Ph.D. (Bristol).
A. J. ABBOTT, M.Sc., Dip. Hort. (Reading).
O. T. G. JONES, B.Sc., Ph.D. (Liverpool).
W. J. REDMOND.
D. J. FISHER.
B. A. NOTTON, A.R.I.C.
D. G. HALLAS.
C. A. ROBINSON, B.Sc. (Birm.). (*Appointed 7 January, 1957*).
J. JARRETT.
MISS T. C. N. GOODMAN, B.Sc. (Lond.). (*Resigned 30 June, 1957*).
D. P. HUCKLESBY, B.Sc. (Lond.).
M. A. WRIGHT.
J. S. CHALLICE. (*On National Service from 6 December, 1956*).
G. L. MABEY.
G. J. DICKES.
M. L. PASSEY. (*Resigned 31 December, 1957*).
J. K. FAULKNER.
M. W. J. HEYES.
D. M. JAMES.
B. V. PALMER. (*Resigned 26 October, 1957*).
MISS K. A. TAYLOR.
MISS J. M. BRADFORD. (*Appointed 11 February, 1957*).
MISS M. FRANKLIN. (*Appointed 1 September, 1957*).
MISS M. POULSON. (*Appointed 9 September, 1957*).
D. J. JONES. (*Appointed 14 October, 1957*).
E. F. WATSON. (*Appointed 1 November, 1957*).

CONTENTS.

	PAGE
Introduction <i>H. G. H. Kearns, Director</i>	11
Summary of Research, 1957	23
Pomology :—	
Rootstocks and stembuilders for cider trees : nursery trial <i>A. I. Campbell</i>	48
Male sterility in Bristol Cross pear <i>D. Wilson</i>	52
Virus diseases of fruit trees : VI. Graft transmission of chat fruit. <i>L. C. Luckwill</i>	56
The propagation of gooseberries : VI. The influence of source on the rooting of hardwood cuttings <i>Barbara A. Rake</i>	59
The classification of gooseberries : I. Useful characters for the classification and identification of varieties <i>Barbara A. Rake</i>	60
Leaf-bud propagation of a virus-tested loganberry clone <i>E. W. Hobbs and A. I. Campbell</i>	65
The control of bindweed in black currants <i>L. C. Luckwill and A. I. Campbell</i>	68
Plant Nutrition : Fruit—	
Soil conditioners : II. The effect of HPAN and VAMA on the yield of strawberries <i>C. Bould</i>	71
Plant Pathology :—	
Spray application problems : XLII. Mercury deposits on apple fruits and foliage <i>J. T. Martin and J. A. Pickard</i>	76
Spray application problems : XLIII. Note on the preparation of Bordeaux mixture <i>E. Somers</i>	82
Studies on the natural protective covering of plants : II. The wax and cutin of leaves and fruits <i>J. T. Martin, R. F. Batt and Margaret F. Roberts</i>	84
Preliminary tests of potential orchard fungicides <i>R. J. W. Byrde and Nora M. Waugh</i>	89
Spraying experiments against apple scab at Long Ashton, 1957 <i>R. J. W. Byrde, G. M. Clarke and C. W. Harper</i>	93
A preliminary comparison of the temperature-germination relationships of ascospores and of conidia of the apple and pear scab fungi (<i>Venturia</i> <i>inaequalis</i> and <i>V. pirina</i>) <i>D. Wheatley</i>	97
The reduction of orchard sources of <i>Gloeosporium</i> disease <i>R. O. Sharples</i>	105
Observations on the mode of perennation of apple mildew <i>R. T. Burchill</i>	114
Spray application problems : XLIV. A compressed air nozzle for small-volume spraying <i>T. E. Cobbald</i>	123
Spray application problems : XLV. The performance of a power knapsack mist sprayer <i>T. E. Cobbald</i>	127
Cider and Fruit Juices :—	
The activity of pectin methylesterase in black currants : progress report <i>Margaret E. Kieser, A. Pollard and D. J. Sissons</i>	134
Domestic Food Preservation :—	
Storage of frozen bacon, brawn and venison <i>Margaret Sturdy and Alice Crang</i>	137
Willows :—	
Cricket bat willows : sale and utilization of the Long Ashton trees <i>K. G. Stott</i>	143
Meteorology :—	
Meteorological records, 1957 <i>G. E. Clothier</i>	156
Publications, 1957	157

INDEX, 1953-1957.

Author index to papers in the Long Ashton Annual Reports from 1953 to 1957	163
Subject index to titles of papers in the Long Ashton Annual Reports from 1953 to 1957	171



PROFESSOR T. WALLACE

PROFESSOR T. WALLACE.

Professor T. Wallace, C.B.E., M.C., D.Sc., F.R.I.C., V.M.H., F.R.S., retired from the Directorship of Long Ashton Research Station on 30th September, 1957, on reaching the age limit. He was appointed to the Station as Agricultural Chemist in 1919, became Deputy Director in 1923 and Director of the Research Station and the National Fruit and Cider Institute in 1943. In the University of Bristol he held the appointment of Lecturer in Agricultural Chemistry from 1919 to 1933, Reader in Agricultural Chemistry from 1933 to 1943 and Professor of Horticultural Chemistry from 1943 to 1957.

Professor Wallace's work has had a profound influence on horticultural science. Within two years of his appointment at Long Ashton he published the first of his many classic papers on the employment of sand-culture methods for the study of crop nutrition. From 1921 to 1939 he worked mainly with fruit, correlating his results at Long Ashton with observations made in surveys of the fruit-growing areas of the West Midlands. An immediate outcome of this work was his demonstration that the widespread and crippling disorder of marginal leaf scorch was a symptom of potash deficiency, amenable to correction by suitable manurial treatment. The close and friendly contacts made by Professor Wallace with the fruit-grower ensured the ready acceptance by the industry of his recommendations.

From 1940 onwards, Professor Wallace extended his work to include the principal farm and vegetable crops, with results that are epitomized in his book "*The diagnosis of mineral deficiencies in plants by visual symptoms: a colour atlas and guide*," first published in 1943. These comprehensive studies on crop nutrition have benefited the whole farming community.

A later phase of the work has been the detailed study of problems of trace-element nutrition, a topic in which Professor Wallace became the recognised authority. Under his guidance, this subject was explored by a group of post-graduate workers at Long Ashton, who in 1952 were constituted as the Agricultural Research Council Unit of Plant Nutrition (Micro-Nutrients), having Professor Wallace as Honorary Director. His standing in this field was further recognised by requests for advice which took him to Australia, New Zealand, the United States, France, Holland, Italy, Spain and Austria, and stimulated a constant flow of research workers from these countries to Long Ashton.

During the period of Professor Wallace's Deputy-Directorship and Directorship the scientific staff of the Station increased sevenfold, with a corresponding rise in equipment and facilities. The solutions of the problems resulting from this rapid growth were largely due to the unremitting care and thought that Professor Wallace devoted to all aspects of the Station's activities. Outside of Long Ashton, his advice was also widely sought. He assisted in the post-war reorganisation of the agricultural research and advisory services, and serves on many technical committees of the Agricultural Research Council, the National Agricultural Advisory Service and the Experimental Horticulture Stations. In 1953 he was appointed to the Agricultural Improvement Council. His services to the nation were recognised by the award of the C.B.E. in 1946, and his scientific eminence by his election to the Fellowship of the Royal Society in 1953.

Members of the Long Ashton staff and all others who consulted him gratefully remember his wise counsel and unfailing help. Long Ashton looks with pride at his long and distinguished record, and all who have been privileged to know Professor Wallace will wish him every happiness in his retirement.

R. W. M.

INTRODUCTION.

By H. G. H. KEARNS, Director.

Professor Wallace retired on 30th September after serving the Research Station for thirty-eight years. He was succeeded by Dr. H. G. H. Kearns, who was appointed to the Directorship and to the Chair of Agricultural and Horticultural Science by the Council of the University. Professor Kearns remains head of the Entomology Section; he has been a member of the University staff since 1926 and of the Station since 1931. Professor Wallace has consented to remain Honorary Director of the A.R.C. Unit of Plant Nutrition (Micro-nutrients).

Professor Wallace's retirement was marked by the presentation at the University on 13th November of a Testimonial Fund contributed by over 300 friends who wished to express their good wishes to Mrs. Wallace and himself. A portrait of Professor Wallace, painted by Mr. John Whitlock, was presented to the Station by the National Fruit and Cider Institute on this occasion; the Station library also received from the Herefordshire N.F.U. the valuable book *Pyrus Malus Brentfordensis*, published in 1831; this had been obtained from the library of the Rev. Cecil L. Dunkerley of Collingtree Rectory, Northampton. On 2nd October the Station Staff presented Professor and Mrs. Wallace with a greenhouse, erected at their new home in Nailsea. The sincere appreciation and good wishes of all members of the Station were expressed in a typically humorous speech by Mr. Marsh; a photograph of the Station staff was taken, and a copy autographed by all members was later given to Professor and Mrs. Wallace. Wives of academic staff had earlier made a separate presentation to Mrs. Wallace in appreciation of all she had done for them.

The close association with the East Malling Research Station established by Professor Wallace will be continued, Professor Kearns succeeding him as a member of the Governing Body and Executive Committee of that Station. Relations with the N.A.A.S. and A.I.C. committees will also be maintained, Professor Kearns having been appointed in Professor Wallace's place to the advisory committees of Efford, Luddington and Rosewarne Experimental Horticulture Stations, Rosemaund Experimental Husbandry Farm and the National Fruit Trials, Brogdale, to the N.A.A.S. Fruit Group and the A.I.C. Fruit and Vegetable Working Parties.

Collaboration with the N.A.A.S. was continued during 1957. The Annual Refresher Course for N.A.A.S. and L.E.A. Officers was held at the Station on 2nd and 3rd July; the Provincial Directors were welcomed to Long Ashton during their visit to the South-West Province on 4th June, and they were also present when Professor Wallace gave a talk on the work of Long Ashton at the conference for County Agricultural Officers held at the Royal Agricultural College, Cirencester, on 9th April. The Advisory Chemists visited the Station on 9th July.

With the aid of a grant from the Colonial Development and Welfare Scheme, special investigations on spray techniques were continued on behalf of the Colonial territories. Collaborative work has been undertaken on the control of Nutfall bugs of coconuts in Kenya and in the British Solomon Islands, and on problems of coffee in Kenya. Mr. H. R. Mapother left in November for a four months' visit to North Borneo, taking with him field and laboratory

equipment for an investigation on the spraying of *Abaca* (hemp) for the control of the aphid vector of Bunchy Top Virus. The Director is a member of the Colonial Office Pesticides Research Committee and Chairman of the Sub-Committee on Spray Applications.

At the request of the Colonial Office, assistance is being given with the testing of soil samples from the Falkland Islands. In the first instance Dr. Webb will carry out pot experiments and chemical and biological assays for major and trace elements. Dr. Webb visited the Gambia in October in connection with a research programme to study soil deficiencies in that territory.

Professor Wallace has accepted the invitation of the Colonial Office to head a scientific team to investigate in 1958 the research needs of the citrus industry in the British Caribbean Area. He has also accepted the invitation of the Food and Agricultural Organisation to collaborate in a Co-operative Research Project on Trace Elements which they are sponsoring in Europe. He was one of the Chairmen at a symposium organised by the Society of Chemical Industry on the subject of "Trace Elements in Soils, Plants and Animals," held at Wills Hall, Bristol, from 10th to 12th April. A number of overseas visitors were among the 100 members; papers were contributed by seven members of Station staff. The members of the symposium visited the Station on 12th April.

Professor Wallace has co-operated in the preparation of an exhibit demonstrating minor element deficiencies in plants for the Universal and International Exhibition to be held in Brussels in 1958. On 6th March he delivered the Fernhurst Lecture of the Royal Society of Arts on the subject of "Trace Elements in Plant Nutrition." On 9th February he acted as Chairman of the Grammar School Section of a conference arranged by the Institute of Education of Bristol University to discuss openings for boys and girls in agriculture with teachers in primary and secondary schools. With Dr. Kearns, Mr. Marsh and Dr. Martin he visited the Lenton Experiment Station, Nottingham, from 22nd to 24th May at the invitation of Boots Pure Drug Co. Ltd.

Dr. Pollard and members of the Cider Section received a visit from the Director, Dr. A. H. Cook, and members of staff of the Brewing Industry Research Foundation, Nutfield, on 3rd May. Professor Kearns, Mr. Marsh, Dr. Bould and Mr. Hobbs were speakers at the Malvern Fruit Conference on 12th November. Dr. Kearns, Dr. Martin, Dr. Nicholas and Dr. Woodcock gave talks at a meeting of the A.R.C. Technical Committee on Insecticidal and Fungicidal Research, organized by Dr. Martin and held at Manor Hall, Clifton, from 28th to 30th March. The Committee visited Long Ashton on 29th March.

At the Pershore Institute of Horticulture's second residential course in horticultural craftsmanship, from April 23rd to 30th, Mr. Campbell gave practical nursery demonstrations to 42 teachers of gardening and rural science.

Dr. E. Somers and Dr. D. Wilson have been awarded Postdoctorate Fellowships of the National Research Council of Canada, tenable for one year from 1st October, 1957. Dr. Somers, Physical Chemist in the Chemistry Section, left on 3rd October for the Science Service Laboratory, London, Ontario, where he is working under the directorship of Dr. Hubert Martin, a former member of the Long Ashton staff. Dr. Wilson, the Station's Plant Breeder, left on 17th October for the Central Experimental Farm, Ottawa.

News of friends of the Station must include a reference to Professor Barker, whom we were very glad to see as usual on Cider Sampling Day, although he had undergone a serious operation in January. A telegram of congratulations

and good wishes was sent to Lord Bledisloe, Chairman of the Agricultural Committee 1920-1925, on his 90th birthday on 21st September.

We record with great regret the death on 16th November of Mr. C. T. Gimingham, O.B.E., who was Agricultural Chemist at Long Ashton from 1912 to 1919. For many years he was on the staff of the Ministry of Agriculture's Plant Pathology Laboratory, Harpenden, of which he became Director. The news of Mr. Gimingham's death came as a sudden shock to Long Ashton staff, as only three days before he had attended the presentation ceremony for Professor Wallace: his presence had given especial pleasure because it was at his suggestion that in May, 1919, Professor Wallace had joined the Long Ashton staff as his assistant, after working with him in the Anti-gas Department of the Ministry of Munitions during the 1914-18 War.

We are very happy to record the election of Sir William Slater, K.B.E., Secretary of the Agricultural Research Council, to the Fellowship of the Royal Society in May, 1957. Other honours that have given us much pleasure are the awards of C.B.E. to Professor J. L. M. Morrison, member of the Agricultural Committee, and to Professor E. L. Hirst, member of that committee from 1936 to 1944: and of O.B.E. to Mr. T. N. Hoblyn, of East Malling Research Station and member of the Long Ashton Finance & Business Sub-Committee, to Professor A. E. Muskett, member of the A.R.C. Technical Committee for Research on Cider and Fruit Juices, and to Mr. H. Fairbank, Director of the N.A.A.S. Luddington Experimental Horticulture Station.

There have been three changes in representation on the Governing Body of the National Fruit and Cider Institute: Mr. H. R. Stephens, M.B.E., has succeeded Major Mealing as one of the two representatives of Gloucestershire County Council: Mr. H. M. Wadham has been elected by the Gloucester Branch of the N.F.U., and Mr. R. S. Graham by the Somerset Branch of the N.F.U. in succession to Mr. Medley.

The first annual report to Parliament of the activities of the A.R.C. was submitted by the Council at the end of March. It covered the period 1st April, 1956-31st March, 1957, and included reports on the work of the Station and of the A.R.C. Unit of Plant Nutrition (Micro-nutrients).

Towards the end of the year the A.R.C. introduced economy measures in support of the Government's endeavour to prevent further inflation. As a result certain temporary restrictions were placed on the appointment of new staff; these have prevented the filling of new posts and the replacement of staff in vacant posts.

By the acquisition of an accounting machine and the appointment of a machine operator, a mechanised procedure for the calculation of salaries and wages was introduced into the office at the beginning of November.

Staff.

The following staff changes occurred during the year:—

Appointments to Scientific Staff.

Dr. D. F. Downing was appointed from 1st January, 1957, to assist Dr. Woodcock in Organic Chemistry. Dr. Downing is a graduate of Bristol University, where he obtained B.Sc. Honours Chemistry in 1952. From 1952 to 1955 he carried out research work under the direction of Professor Wilson Baker, as a result of which he was awarded the Ph.D. degree. He was then

awarded a Fulbright travel grant which enabled him to take up a post-doctoral fellowship at the University of California at Los Angeles, where he worked with Professor T. A. Geissman until his appointment to the Long Ashton staff. This work entailed the use of labelled carbon compounds and chromatographic techniques to determine the route of the synthesis of flavonoid compounds in plants. Before entering Bristol University in 1948, Dr. Downing had served for four years in the Army, being demobilised with the rank of Lieutenant.

Dr. B. D. Smith joined the staff on 1st October, 1957, to investigate the problem of Big Bud mite of black currants under a Special Grant from the A.R.C. He graduated B.Sc. (General) in the University of Sheffield in Zoology and Botany in 1953, and a year later was awarded a Special Honours B.Sc. in Zoology. He then obtained a Training Grant for Entomology from the Agricultural Research Council for one year and, with the award of a Council Research Studentship for 1955, he was able to continue for a second year research on aphid populations, under the supervision of Professor O. W. Richards at the Imperial College of Science and Technology. As a result of this work he was awarded the Diploma of the Imperial College in October, 1957, and the degree of Ph.D. in February, 1958.

Mr. D. V. Richmond was appointed from 1st August to assist Dr. Martin with analytical investigations. Mr. Richmond graduated B.Sc. in Chemistry and Botany in London University in 1945 and, after experience in industrial laboratories between 1945 and 1956, entered the University of Bristol for the course leading to the Diploma in Horticultural Science. During part of this time he worked under the supervision of Dr. Somers at Long Ashton.

Mr. R. O. Sharples was appointed to the staff for the period 11th September, 1957, to 30th June, 1958, under a special grant from Boots Pure Drug Co. Ltd., in order to complete the work on *Gloeosporium* rot of apples which he had been carrying out under the supervision of Mr. Marsh during his tenure of the Boots' Research Scholarship in the previous two years.

Appointments to Assistant Staff.

Mr. P. R. Colegate, who succeeded Miss Beresford as Librarian on her resignation, joined the staff on 18th November, 1957. Since 1946 he has worked in Malvern and Hampstead Public Libraries and has served two years as editorial assistant with a publishing firm.

Mr. C. A. Robinson, Assistant Experimental Officer, was appointed Greenhouse Officer for the Unit of Plant Nutrition on 7th January, 1957, to succeed Mr. C. S. Gundry, who was transferred to the Station staff to take charge of the new greenhouses. Mr. Robinson graduated B.Sc. in Botany in 1954 in Birmingham University, and spent the following two years on National Service in the Royal Corps of Signals as a radio technician and technical instructor.

Miss G. M. Fawkes, Assistant Experimental Officer, was appointed Microbiologist in the Domestic Food Preservation Section from 1st September, 1957, in succession to Mrs. J. M. Bowcott, who resigned. She graduated B.Sc. (General Honours) in Bristol University in 1957 in Microbiology, Botany and Chemistry.

Miss K. Guite, Assistant Experimental Officer, was appointed to succeed Mrs. J. C. B. Waddington in the Cider and Fruit Juices Section to assist Dr. Beech in Microbiology from 22nd July. She graduated B.Sc. (General Honours) in Bristol University in 1957.

Mr. K. G. Jones, Assistant Experimental Officer, was appointed Instrument Maker in the Workshops Section from 1st October, 1957. The son of Mr. G. H. Jones, Station Photographer, he trained as a scientific instrument maker in the Physics Department of Bristol University between 1946 and 1952, and after completing his National Service returned to that Department in 1954.

Miss J. M. Bradford, Assistant (Scientific), Unit of Plant Nutrition, from 11th February, 1957.

Miss J. Bird, Assistant (Scientific), Cider Microbiology, from 1st March, 1957.

Mr. P. Bale, Assistant (Scientific), Nutrition of Fruit Plants, from 1st October, 1957.

Mr. R. S. Cole, Assistant (Scientific), Workshops, from 3rd October, 1957.

Mr. T. W. Cox, Assistant (Scientific), Willows, from 9th September, 1957.

Miss V. L. Fowler, Assistant (Scientific), Cider Chemistry, from 16th September, 1957.

Miss A. J. Knight, Assistant (Scientific), Nutrition of Fruit Plants, from 2nd September, 1957.

Miss S. J. Sage, Assistant (Scientific), Statistics, from 2nd September, 1957.

Miss M. Franklin, Assistant (Scientific), Unit of Plant Nutrition, from 1st September, 1957.

Mr. D. J. Jones, Assistant (Scientific), Unit of Plant Nutrition, from 14th October, 1957.

Miss M. Poulson, Assistant (Scientific), Unit of Plant Nutrition, from 9th September, 1957.

Resignations : Assistant Staff.

Miss S. M. Beresford, Librarian, from 10th August, 1957.

Miss P. M. Jackson, Assistant Experimental Officer, Analytical Chemistry, from 30th April, 1957.

Mrs. J. C. B. Waddington, Assistant Experimental Officer, Cider Microbiology, from 31st July, 1957.

Mrs. J. M. Bowcott, Assistant Experimental Officer, Domestic Food Preservation, from 12th July, 1957.

Miss V. W. Rogers, Assistant Experimental Officer, Organic Chemistry, from 16th August, 1957.

Miss S. J. Locke, Assistant Experimental Officer, Cider Chemistry, from 17th August, 1957.

Mrs. J. M. Fielding, Assistant (Scientific), Cider Microbiology, from 2nd February, 1957.

Mrs. A. J. Megenis, Assistant (Scientific), Pomology, from 31st October, 1957.

Mr. B. V. Palmer, Assistant (Scientific), Unit of Plant Nutrition, from 26th October, 1957.

Sandwich Course.

Mr. J. K. Faulkner, Assistant Experimental Officer, Unit of Plant Nutrition, was released for full-time study for the period 1st October, 1957–30th April, 1958, to study for the A.R.I.C. and B.Sc. (External, London) examinations at Bristol College of Technology. Mr. Faulkner will be released for a further period of full-time study under the Sandwich Course scheme from 1st October, 1958–30th April, 1959.

Appointments to Administrative Staff.

Miss P. Curtis, Shorthand Typist, from 25th March, 1957, to succeed Miss N. K. Bullock.

Miss C. Hales, Shorthand Typist, from 10th October, 1957, to succeed Miss M. J. Hathway.

Mrs. J. M. Bendall, Machine Operator/Accounting Clerk, from 1st November, 1957.

Miss P. M. Heyward, Junior Clerk, from 1st January, 1957, to succeed Miss D. A. Pearce, transferred to Library staff.

Retirement : Administrative Staff.

Miss E. M. Matthews, Shorthand Typist, from 31st December, 1957. Miss Matthews had served the Station for 22 years, and retired under the age limit regulations, after a lengthy period of ill-health.

Resignations : Administrative Staff.

Miss N. K. Bullock, Shorthand Typist, from 23rd March, 1957.

Miss M. J. Hathway, Shorthand Typist, from 12th October, 1957.

Visits Abroad.

Dr. E. Somers and Dr. D. Wilson were awarded Postdoctorate Fellowships of the National Research Council of Canada for one year. Dr. Somers left on 3rd October, 1957, for the Science Service Laboratory, London, Ontario, and Dr. Wilson on 17th October, 1957, for the Central Experimental Farm, Ottawa.

Mr. H. R. Mapother left on 11th November, 1957, for North Borneo to investigate Bunchy Top disease of *Abaca* (hemp), at the request of the Colonial Office.

Dr. R. A. Webb re-visited the Gambia from 17th September to 19th October in connection with field trials with fertilizers.

Mr. R. W. Marsh and Dr. J. T. Martin attended the International Congress on Crop Protection at Hamburg from 8th to 15th September, 1957, when Mr. Marsh contributed a paper entitled "A survey of fungicide spraying practice in England." Dr. Martin visited the Bayer Laboratories at Bonn after the congress.

Dr. F. W. Beech visited the Centraalbureau voor Schimmelcultures, Yeast Division, Delft, Holland, from 15th to 20th July, to study the International Yeast Collection and to discuss with the leading workers at that centre his work on cider yeasts, in particular their classification.

Dr. D. J. D. Nicholas attended the Third Fertilizer World Congress in Heidelberg from 9th to 12th September and gave a paper entitled "Fertilizers as factors in improving the quality of plant products."

Degrees, Honours, etc.

Professor Wallace was elected Emeritus Professor of Horticultural Chemistry in the University of Bristol. He was elected a Membre Etranger de l'Academie d'Agriculture de France on 3rd April: he was awarded a Veitch Memorial Gold Medal by the Royal Horticultural Society; he has been elected a Life Member of the East Malling Association, and Associate Editor of the Journal of Horticultural Science of which he had been Joint Editor since 1943.

Mr. F. W. Beech was awarded the degree of Ph.D. (Bristol) for a thesis entitled "The incidence and classification of cider yeasts."

Mr. M. L. Passey obtained the A.R.I.C. qualification as a result of examination.

Buildings and Land.

Authority was received during the year from the Treasury, through the Agricultural Research Council, for the preparation of detailed plans and specifications for a laboratory and office building and for a canteen and common-room. Completion of the plans, however, depends on a decision regarding the type of heating system to be adopted. In view of national economies there is still a possibility that commencement of the building programme may be delayed, but it is hoped that it will be possible to obtain tenders early next year.

Capital grants have been received from the Agricultural Research Council to provide additional initial equipment and facilities for the new greenhouses, for the electrical rewiring of the main laboratories, for a partitioned building to include a workshop for the Plantations staff and an anthracite store, and for other items of a special nature not covered by the general maintenance grant.

The room in the main laboratory building previously used for photography has been redecorated and adapted for Professor Wallace's use, and the Director's room has been re-arranged, redecorated and refurnished for Professor Kearns.

Several members of staff have been granted permission to build their own houses on plots of land in Providence Lane, leased from the Research Station.

Six acres of orchards no longer required for experimental work have been grubbed and will be rested in grass in preparation for fresh plantings in 1959/60. Seven acres of dessert pears were planted for investigations into nutrition, spray techniques and spray damage. One acre of a number of varieties of perry pears on Quince A rootstock was planted in grass for pomological studies. The plot of dwarf pyramid apple trees was increased to six acres by the addition of 750 trees; these trees are used for a wide range of investigations. On the main Pathology plot (23) about $\frac{3}{4}$ acre of Cox's Orange Pippin, Lord Lambourne and Cheddar Cross was close planted for special purposes.

Other Activities.

Members' Day.

The Annual General Meeting and Field Day for Members of the National Fruit and Cider Institute was held on 17th July. Demonstrations included the newly-found rosette disease of perry and Conference pears budded on Quince A rootstocks, the establishment of varieties of perry pear as bush trees, the effects of grass cover on young dessert apples and the varietal characteristics of black currants. Members had their first opportunity of inspecting the new greenhouses.

At the meeting Professor Wallace addressed Members for the last occasion as Director; he traced the history of the Institute from its inception in 1903 to the present time, and outlined its development from the small research unit founded by the National Fruit and Cider Institute, consisting of Professor Barker and two or three members of staff, to its present status as a national Research Station, with a total staff of 230. He was unanimously elected a Life Member of the Institute.

Cider Sampling Day.

The annual Cider Sampling Day was held on 2nd May and was well attended by cider makers, cider fruit growers and others interested in the industry.

Both ciders and perries were shown and emphasis was placed on ciders made from the new List of Recommended Varieties. These aroused interested discussion. Other ciders and perries illustrated the effects of the control of micro-flora on cider quality.

Visitors.

The number of organized parties visiting the Station was 46, compared with 33 in 1956. Visitors included the Agriculture and Microbiology Groups of the Society of Chemical Industry, Provincial Directors and Soil Chemists of the N.A.A.S., members of the A.R.C. Technical Committee on Insecticide and Fungicide Research and the Director and staff of the Brewing Industry Research Foundation.

Organized Parties, 1957.

Andover and District Winemakers' Circle.
 A.R.C. Technical Committee on Insecticide and Fungicide Research.
 Bedminster Down Social Club.
 Brewing Industry Research Foundation, Nutfield.
 Bristol University, Freshmen.
 Bristol University, Veterinary Students.
 Cheltenham Ladies' College.
 Clifton High School for Girls.
 College of St. Matthias, Barrow Court.
 Colombo Plan Students.
 Devon School of Agriculture and Horticulture.
 Domestic Preservation Courses (2).
 Dorset Rural Science Teachers.
 Herefordshire N.F.U.
 Industrial Medical Officers' Association.
 Institute of Bankers, Bristol Centre.
 Institute of Hospital Administrators.
 Keynsham Townswomen's Guild.
 Kingswood and District Photographic Society.
 Kingswood School, Bath.
 Messrs. T. C. Marsh, Clifton, Employees.
 Monmouthshire Women's Institutes' Produce Guild.
 N.A.A.S. and L.E.A. Horticultural Officers, Refresher Course.
 N.A.A.S. Provincial Directors.
 N.A.A.S. Soil Chemists.
 National Vegetable Research Station, Wellesbourne.
 Newton Park College, Bath.
 Nottingham University, Department of Horticulture.
 Oxford University, Department of Forestry.
 Reading University, Horticulture Students.
 Redland High School Field Club.
 St. Dunstan's Social Club, Bedminster.
 Sea and Air Port Health Authorities' Association, Annual Conference.
 Society of Chemical Industry, Microbiology Group.
 Society of Chemical Industry, Agriculture Group.
 Somerset Beekeepers' Association.
 Somerset Farm Institute, Horticultural Students.
 Somerset Fruit Growers' Club.
 Studley College, Students.
 Sturminster Area Community Association, Ladies' Group.
 Surrey Beekeepers' Association.
 Teachers of Domestic Subjects, South Wales and Monmouth Association.
 Waterperry School of Horticulture.
 Weston-super-Mare Central Townswomen's Guild.
 Weston-super-Mare Grammar School for Girls.

Visitors from Overseas, 1957.

- Australia :* Dr. E. F. L. J. Anet, Sydney.
Mr. Ralph Doepel, Perth, Western Australia.
Dr. L. J. Flentje, Waite Institute, Adelaide.
Mr. D. Francis, Sydney.
Mr. R. W. B. Gantrell, Orange, N.S.W.
Dr. C. T. Gates, Griffith.
Dr. P. Geier, C.S.I.R.O., Canberra.
Mr. W. R. Jamieson, Perth, Western Australia.
Mr. B. S. Janes, Icianz Ltd., Melbourne, Victoria.
Mr. H. Parry Brown, Department of Agriculture, Sydney.
Mr. W. V. Single, Department of Agriculture, N.S.W.
- Austria :* Dr. G. Hauser, Vienna.
- Belgium :* Dr. R. Aerts, Gorsem, St. Trond.
Dr. G. Gilles, Gorsem, St. Trond.
- Canada :* Dr. A. A. Beaulieu, St. Jean, Quebec.
Mr. P. B. Chambers, Haramata, B.C.
Dr. H. Martin, London, Ontario.
Dr. and Mrs. H. R. McLarty, Summerland, B.C.
Mr. H. A. Pass, Montreal.
- Canary Islands :* Dr. I. G. Caldas, Tenerife.
- Ceylon :* Mr. W. R. N. Nathanael, Coconut Research Institute.
Mr. G. Phimister, Colombo.
- Costa Rica :* Professor and Mrs. F. Hardy, Turrialba.
- Czechoslovakia :* Mr. J. Starke, Prague.
- Denmark :* Mr. Niels Schmidt, Sohns.
Mr. C. Sørensen, Copenhagen.
- Finland :* Dr. J. Saho, Piikkio.
- France :* Mdlle. Annie Bosselu, Paris.
M. P. Ribereau-Gayon, Bordeaux.
- Gambia :* Mr. L. J. Marenah, Department of Agriculture.
- Ghana :* Mr. J. C. Burridge, W.A.C.R.I., Tafo.
Mr. A. Maddison, W.A.C.R.I., Tafo.
Mr. A. Pickles, Accra.
Mr. M. A. Vickars, W.A.C.R.I., Tafo.
- Germany :* Mr. T. Jung, Hanover.
Dr. K. Raschke, Hanover.
Dr. Von Uexkull, Hanover.
- Holland :* Dr. J. H. Becking, Wageningen.
Dr. L. K. Wiersum, Groningen.
- India :* Mr. B. S. Bhatia, Mysore.
Mr. and Mrs. C. A. P. Davies, Assam.
Dr. S. K. Mukherjee, Calcutta.
Mr. S. Nagappa, Education Officer, High Commission of India.
Mr. N. S. S. Srivastava, Madras.
- Israel :* Miss Hadasa Avigdor, Ministry of Agriculture.
Mr. A. Bar-Akiva, Rehovot.
Mr. A. Gur, Rehovot.
Dr. C. Resnick, Ministry of Agriculture.
- Jamaica :* Mr. R. Leach, Kingston.
Mr. P. D. Manser, Sugar Research Department.
Mr. Hugh Payne, Department of Agriculture.
- Japan :* Mr. D. Kushibiki, Tokyo.
- Kenya :* Mr. J. F. Graham, Department of Agriculture, Nairobi.
- Malaya :* Mr. C. G. Akhurst, Rubber Research Institute.
Mr. V. M. Shorrocks, Rubber Research Institute.
- New Zealand :* Mr. M. J. Adamson, Department of Agriculture, Nelson.
Dr. E. G. Bollard, Auckland.
Mr. M. Fieldes, Wellington.
Mr. A. D. Masters, N.Z. Apple and Pear Board, Hastings.
Mr. K. J. McNaught, Rukuhia Soil Research Station, Hamilton.
Miss Jean Miller, Department of Agriculture, Wellington.
Mr. A. Osborne, Wellington.
Miss Dorothy Read, Cawthron Institute.
Mr. R. E. Robinson, Stoke, Nelson.
Mr. K. Ross, Wellington.
- Nigeria :* Mr. S. A. Akinleye, Abeokuta, W. Nigeria.
Mr. E. J. Gregory, Department of Agriculture, N. Nigeria.

	Mr. and Mrs. L. S. Thompson, Ibadan, W. Nigeria.
	Mr. D. J. Wheeler, Abeokuta, W. Nigeria.
<i>Pakistan :</i>	Mr. D. H. Khan, Dacca.
<i>Poland :</i>	Professor T. Litynski, Cracow University.
	Dr. M. S. Niklewski, Szczecin University.
<i>Rhodesia :</i>	Mr. S. J. T. Mattick, African Explosives and Chemical Industries Ltd.
<i>South Africa :</i>	Dr. D. G. Ashby, Stellenbosch.
	Mr. C. F. Cresswell, Grahamstown.
	Mr. E. R. Estcourt, Somerset West.
	Professor E. S. Twyman, Rhodes University, Grahamstown.
	Mr. E. J. Van Busschbach, Stellenbosch.
	Mr. J. K. Winstanley, African Explosives & Chemical Industries Ltd., Johannesburg.
<i>Spain :</i>	Mr. J. M. Busca, Zumarraga.
	Mr. Lachica Garrido, Instituto Edafologia, Madrid.
	Dr. Perez Geijo, Instituto Edafologia, Madrid.
	Professor E. Vieitez, Pontevedra.
<i>Sweden :</i>	Mr. A. Hartman, Alnarp.
	Mr. A. Johansson, Uppsala.
	Dr. N. G. Nybom, Balsgard.
	Mr. H. Sahlström, Alnarp.
	Dr. E. G. Ullstrom, Pomological Society.
<i>Switzerland :</i>	Dr. Hans Lüthi, Wädenswil.
<i>Tanganyika :</i>	Dr. R. Foster, Arusha.
	Mr. D. Yeo, Arusha.
<i>Tasmania :</i>	Mr. D. Martin, Tasmanian Regional Laboratory, Hobart.
<i>Thailand :</i>	Mrs. V. Thisyamdala, Bangkok.
<i>Trinidad :</i>	Mr. E. H. Iton, I.C.T.A.
	Dr. V. C. Quesnel, Colonial Microbiological Institute.
<i>Turkey :</i>	Mr. G. Karel, Ankara.
<i>U.S.A. :</i>	Dr. N. B. Akkesson, University of California, Davis.
	Mr. J. G. Bald, Los Angeles, California.
	Dr. and Mrs. L. R. Blinks, Stanford University, California.
	Dr. Julian Crane, University of California, Davis.
	Dr. V. R. Gardner, Winter Park, Florida.
	Miss Elizabeth Murphy, University of Maine.
	Mr. Paul E. Primer, Davis, California.
	Mr. G. V. Williams, Disaba, California.
<i>Venezuela :</i>	Dr. R. C. Tincknell, Cagna.
<i>Yugoslavia :</i>	Mr. V. Bosovic, Belgrade.
	Ing. S. Brankovic, Rogatica.
	Mr. L. Joksimovic, Skopje.
	Mr. Naco Siskov, Novi Sad.

Shows and Demonstrations.

Exhibits were staged at the following shows :—

Royal Horticultural Society, Chelsea, May 21st–24th.

Bath and West and Southern Counties, Swindon, May 29th–June 1st.

Students and Voluntary Workers.

We have been glad to welcome Dr. Julian Crane of the Pomology Department, University of California, Davis, this year. He arrived on 27th September to spend a year's sabbatical leave working with Dr. Luckwill. Dr. Crane is an authority on the application of growth substance to fruits, especially figs and apricots.

The Boots Research Scholarship for the two years commencing 1st November, 1957, was awarded to Miss M. F. Roberts, who is working with Dr. Martin on the fractionation of apple wax.

Mr. C. Cresswell, Botany Department, Rhodes University, Grahamstown, South Africa, arrived on 7th October to study with Dr. Hewitt for a higher degree in the University of Bristol.

Mr. Khan Afridi, a postgraduate student from Aligarh Muslim University, India, commenced two years' study under Dr. Hewitt on 8th March. His studies are financed by the Colombo Plan Technical Co-operation Scheme.

Mr. A. Bar-Akiva of Israel is studying techniques in micronutrient research under Dr. Hewitt for one year, whilst holding a British Council Scholarship. He arrived at the Station on 30th September.

At the request of the Colonial Office, Mr. P. B. Tatham began a year's training on 7th October in connection with the nutrition of tree crops, preparatory to taking up an appointment at the West African Institute for Oil Palm Research, Benin, Nigeria. He is working with Dr. Hewitt.

Mr. Arne Johansson of Uppsala, Sweden, arrived on 7th November to spend four months studying cultural methods of agricultural plants in Dr. Hewitt's section.

Mrs. V. Thisyamondala of Thailand, a trainee under the Colombo Plan, spent the first two months of a year's tour in this country studying the preparation and quality evaluation of processed foods with Miss Crang. She arrived on 5th November and left at the end of December. She will be returning in June 1958 for another two months.

Mr. C. J. Hunt was awarded the Memorial Studentship in Cider-making and commenced his six months' period of training on 1st October. He is a nominee of Devon County Council.

Mr. M. W. Case, holder of a Ministry of Agriculture scholarship in horticulture for two years from 1st October, 1956, continued his work in the Pomology Section on the "rosetting" of maiden pear trees.

Mr. R. O. Sharples continued his tenure of the Boots' Research Scholarship until September; he subsequently received an additional grant from Messrs. Boots enabling him to extend his period of work at Long Ashton (see Appointments to Scientific Staff).

Mr. R. T. Burchill, a Ph.D. candidate from the Horticultural Science Laboratories of the University, continued his studies on apple mildew under the direction of Mr. Marsh.

Mr. R. Doepel of the Department of Agriculture, Western Australia, worked in the Plant Pathology Section from 3rd May to 29th June.

Mr. D. Wheatley, a Plant Pathology Diploma student in the Horticultural Science Laboratories, completed his course at Long Ashton during the Summer Term and the Long Vacation.

Social Activities.

This year has seen the formation of a Recreational Club, the aims of which are to promote the social and sport activities of the Station. Membership is open to all members of staff on payment of an annual subscription of 13s., and husbands and wives are welcomed as associate members. The total membership this year has been 162 and, whilst activities are at present limited by lack of building accommodation, a number of social events have been organised with success. Thanks to the generosity of the Finance and Business Sub-Committee, it has been possible to purchase gramophone and recording equipment for the Music Club and for social functions.

The Cricket Club, in its 22nd year, increased the number of its playing members and had one of its most rewarding seasons. Even though the club has no ground of its own, 14 matches were played of which 10 were won. Particularly

gratifying were wins against the Academicals, Somerset Farm Institute, Cannington, and the National Vegetable Research Station, Wellesbourne. The tone of the last match was set by an opening maiden over from Professor Wallace.

The 1957 season was a notable one for the Tennis Club, as early in the year a new hard court was laid in place of the remaining grass court. With two hard courts now available, it has been possible to extend play throughout the year, and membership of the club has increased. Twenty-seven matches were played against other clubs and there were two Open Days. In the Men's League of the Bristol District the team finished third in its group, winning five out of ten matches; a Ladies' Team was also entered. Thirteen friendly matches were played, of which five were won.

The Table Tennis Club continues to function during the lunchtime, and has a membership of twenty. Play against other clubs in the evenings is at present precluded because of the lack of a permanent site for the table.

The Rifle Club, appropriately called "The Magpies," enrolled twenty members in its first year. A grant from the Finance and Business Sub-Committee augmented the club funds and made it possible to purchase equipment and to construct a 25 yards outdoor miniature range at the Station. During the year weekly meetings were held in the O.T.C. range at the University; in the summer large-bore shooting was arranged on the ranges at Pilning. Several matches were arranged against local teams.

The annual sports fixture with the staff of the National Vegetable Research Station, Wellesbourne, was held on 13th July, when the Wellesbourne staff visited Long Ashton. The occasion was a very enjoyable one, Long Ashton winning the cricket and the tennis laurels going to Wellesbourne.

The Welfare Committee, under the Chairmanship of Dr. Bennett, organized the annual Christmas Party, held again this year at Messrs. Wills' Recreation Hall, Bedminster, on Friday, 20th December.

The Christmas Lunch was arranged by the Canteen Committee and held on Monday, 23rd December.

Acknowledgments.

The Station is indebted to many members of staff who contributed to the smooth change-over in Directorship: in particular, thanks are due to Professor Wallace for the great trouble he took in handing over the affairs of the Station; he was assisted in every possible way by Mr. Leggett. Miss Simpson has had an arduous time in serving two Directors; her decoration and furnishing of their new offices has been much appreciated.

The magnitude of Mr. Greenwood's task in attending to the requirements of visitors and in preparing scripts for publication was realized during his absence through illness in the summer. The Station was fortunate in having Mr. Marsh's assistance in the editing of the Annual Report at this time and Mr. Clothier's help in entertaining our visitors.

Dr. Bennett and his colleagues must be congratulated for their successful efforts to establish the Recreational Club for the social wellbeing of the Station. Dr. Bennett also served as Chairman of the Welfare Committee to whom the Station is indebted for dealing with staff welfare requirements.

The Station is also indebted to those who have carried out the harassing and thankless task of canteen management: Mr. Stott as Chairman of the

Canteen Committee, Miss Margaret Sturdy for her general supervision of canteen arrangements, and Miss Karen Taylor and Miss Anne Turner for arranging menus and ordering provisions.

Mr. Maltby's friends will be sorry to know that a painful attack of emphysema caused him to be absent from the Station from July onwards. Thanks are due to Mr. George Jones for the efficient way in which he has acted as Chief Laboratory Steward.

Dr. Morgan has been appointed by the Finance and Business Sub-Committee as a member of the Plantations Sub-Committee, thereby sharing with the Director the many tasks that arise in connection with the workshops and new buildings. The Station is indebted to Dr. Morgan for his generous assistance to members of Staff with mechanical and electrical problems.

SUMMARY OF RESEARCH, 1957.

Pomology and Plant Breeding.

Plant Breeding.

25 seedling black currants, selected for their exceptionally high ascorbic acid content in 1956 and 1957, are now being propagated with the intention of planting a trial plot to assess more fully their field performance. The collection of *Ribes* species was further augmented and the established bushes have been transferred to a permanent plot for assessment as possible parents in the proposed interspecific crossing programme.

In the cider breeding programme the first family of seedlings is 10 years old and approximately one quarter of the trees are now bearing. Many have already been eliminated on the basis of small fruit size or high susceptibility to mildew; others have been selected for further observation and some of these have already produced enough fruit for small-scale cider making trials. A second group of families, hybrids between various cider varieties and Worcester Pearmain, have been raised in an attempt to produce an early-maturing cider variety of good vintage quality, a requirement of the industry which is not fulfilled by any of the existing varieties.

Investigations during the past two seasons have shown that the pear variety Bristol Cross is virtually male-sterile. Although diploid in constitution, over 90 per cent. of its pollen grains abort at an early stage of development. Thus, although this variety sets heavy crops of fruit when cross pollinated, it cannot be recommended as a pollinator for other varieties (p. 52).

Growth Substances.

A method has been developed for the recovery and quantitative estimation of microgram quantities of synthetic growth substances from plant tissue. The growth substance is extracted from oven- or freeze-dried material with an acid buffer solution, partitioned into ether and adsorbed on a column of activated alumina. It is recovered from the alumina by elution with sodium bicarbonate and is subsequently partitioned into carbon tetrachloride. The *Coleus* petiole abscission test is used for quantitative assay of the purified growth substance.

The method, which has been worked out in co-operation with the Chemistry Section using ^{14}C labelled compounds, is suitable for the recovery of amounts of growth substance of the order of 0.1 to 100 μg . from 1 g. dry weight of tissue. It is being employed in a study of the metabolism of 2:4-dichlorophenoxyacetic acid (2:4-D) and α -naphthalene acetic acid (NAA) by apple leaves in relation to problems of fruit-drop control and fruit thinning. The same method is being employed in co-operative work with the Department of Pomology at Davis, California, for studying the accumulation of 2:4:5-trichlorophenoxyacetic acid (2:4:5-T) in apricot seeds and fruits collected from trees that have been sprayed with this compound to increase fruit size.

Studies of the relationship between the chemical structure of the naphthoxy growth substances and their activity in inducing parthenocarp in the tomato were continued in co-operation with the Chemistry Section. Contrary to expectation, no evidence of antagonism or synergism could be found between active and inactive compounds in this series. Gibberellic acid, on the other hand, showed very marked synergism in combination with both 2-naphthoxyacetic acid (2-NOA) and indole 3-acetic acid (IAA) in the tomato test. In the *Coleus* petiole abscission test gibberellic acid was found to promote abscission at doses as low as 0.001 μg . per petiole, but no clear evidence of synergism with 2:4-D was found.

Chemical thinning trials on apples were this year extended to Winston, a variety that frequently carries a heavy crop of undersized fruits. Some thinning was achieved by spraying with α -naphthalene acetamide (NA m) at 25, 50 and 75 p.p.m. but in no instance was there any gain in the number of fruits of marketable size. Crawley Beauty, on the other hand, sprayed shortly after petal-fall with NA m at 25 p.p.m., yielded $2\frac{1}{2}$ times as many large ($>2\frac{3}{4}$ in.) fruits as unsprayed control trees. Observations on the effect of chemical thinning of different varieties on fruit bud differentiation were continued. Branches of Lane's Prince Albert, which had been thinned in 1956 with NA m , carried in 1957 approximately twice as many blossom clusters as the unthinned control branches, though this difference was not reflected in the final crop yield.

Previous work with Miller's Seedling and Crawley Beauty had shown that the increased drop of young fruitlets that follows a NAA or NA m spray was associated with increased seed abortion induced by the spray. A study of the growth rates of individual fruits of Laxton's Superb on trees sprayed at petal-fall with NAA at 25 p.p.m. showed that, in this variety, although seed abortion is induced, a large proportion of the affected fruitlets fail to abscise and, after a period of retarded growth lasting 2 to 3 weeks, continue to develop to maturity, even in the complete absence of seeds. This explains the failure of NAA as a thinning agent on this variety of apple.

Further experiments, in which NAA was applied to trees that had been previously hand thinned, confirmed that both hormone-induced seed abortion and fruitlet abscission are decreased as competition between fruitlets is reduced, thus indicating that the action of the hormone is an indirect one, possibly associated with a temporary restriction of carbohydrate supply to the fruitlets. In fact, an effect similar to that produced by NAA was found to follow defoliation of branches shortly after petal-fall.

Field trials with 2:4:5-trichlorophenoxy-butyric acid for the control of Bindweed in black currant plantations were an outstanding success. By spraying to run-off with 500 to 1500 p.p.m. of the potassium salt of this acid

a complete kill of the aerial parts and a considerable portion of the root systems of both Field Bindweed and Greater Bindweed was achieved. Spraying was carried out after picking, and no damage was caused to the bushes (p. 68).

The use of 2:4-dichlorophenoxy-ethyl sulphate (2:4-DES) as a herbicide amongst nursery trees was extended during the past season with very satisfactory results. At 4 lb./100 gallons/acre no damage was caused to nursery stock, and weed control in general was good. In trials with the same compound on strawberries some damage was caused to young plants of the variety Redgauntlet sprayed during a very dry spell.

Dormancy.

Observations on potted trees of Lord Lambourne, Worcester Pearmain and Cox's Orange Pippin, which had been given varying exposure to cold during the winter, showed that delayed and abnormal flower development was more marked on those receiving sub-optimal cold treatment than on control trees kept in continuous warmth. Germination tests made at weekly intervals on batches of apple seed stored dry at room temperature have revealed a slight but definite periodicity in their germination capacity throughout the year.

Variety Trials and Cultural Experiments.

In the experiment comparing different planting systems for apples, now in its tenth year from planting, heavy crops were picked from trees growing under each system. The plots in which the permanent bush trees on M.II at 24 ft. apart were interplanted with "fillers" on M.IX became so overcrowded that access to the plot for spraying and grass cutting machinery was difficult: it was in consequence necessary to thin the plot this year. Thinning was carried out after harvest by removing all the "filler" trees with the exception of those in the centres of the squares of permanent trees. The effect of fillers during the first ten years of the life of the plantation can now be seen clearly on the remaining permanent trees, which compare unfavourably in size and spread with similar trees on the open 24 ft. square plant. Winston, which for the past two seasons has produced undersized fruits, showed some improvement in this respect in 1957, though the fruits from trees on M.II were again smaller than those from trees on M.IX.

Total yields of Cox in bushels per acre, over the ten years since planting, have been: Permanent bush (75 M.II p.a.) = 706; Permanent bush (75 M.II p.a.) + fillers (227 M.IX p.a.) = 716 + 1015 = 1731; Cordons (1815 M.II p.a.) = 1737; Dwarf Pyramids (1361 M. II p.a.) = 2307. Yields from Winston were respectively 558; 598 + 1431 = 2029; 1956; 2572 bushels per acre.

A new experiment to compare the growth and cropping of Cox and Worcester grown as dwarf pyramids and as "pillar" trees has been laid down. The trees, planted as maidens in the winter 1955-56, are making good growth, but no crops have yet been recorded.

In an experiment to compare the cropping of sixteen varieties of black currant, including four unnamed Long Ashton seedlings, the bushes produced their second crop and all except Amos Black gave heavy yields. The unsatisfactory performance of Amos Black was due to heavy berry drop just before ripening, possibly associated with an exceptionally dry spell of weather at this time.

An experiment started three years ago to investigate the value of various chemical treatments for the destruction of apple tree butts and roots left after felling has not so far given any decisive results. It was hoped that the treatments would not only hasten decay but also prevent attack by *Armillaria mellea*. So far this fungus has not appeared on either the treated or untreated stumps, although it is known to be present in this orchard.

Rootstocks and Propagation.

Investigations were continued on the "rosette" disease of maiden pears worked on Quince A, described in the Annual Report for 1956. A survey of fruit tree nurseries in the South of England in May and June revealed that this trouble was widespread, only 4 out of 17 nurseries visited being free from the disease. Conference was affected in 12 nurseries, but a few varieties, notably Catillac, appeared healthy in all nurseries and are probably resistant. The perry variety Rock also appears resistant and, by using this variety as an interstock, rosette in Blakeney Red and Conference can be partially overcome. Rosette in Conference can also be overcome by grafting on to Quince A stocks in the spring, rather than budding in the summer. Marked differences in the percentage of rosetted trees were found in an experiment in which Conference buds from different sources were worked on to a uniform batch of Quince A stocks. The variety Blakeney Red, which shows the most extreme form of rosette on Quince A, also failed to grow when budded on seedling quince, or when budded directly on to root pieces of Quince A, though this variety always makes good growth on seedling pear stocks. These observations are consistent with the hypothesis that rosette is caused by a complex of two viruses, one of which is carried in certain Quince A stocks and the other in certain pear varieties such as Conference. Blakeney Red appears to carry both components of the virus complex, which manifest themselves as rosette whenever this variety is worked on to quince.

Confirmation of the virus nature of chat fruit in Lord Lambourne was obtained by inoculating healthy dwarf pyramid trees of this variety with buds or bark chips from chatted trees. Of 30 trees inoculated in the summer of 1956, 13 produced severely chatted fruits in 1957 (p. 56). Other trees of Lord Lambourne inoculated with suspected "false sting" virus failed to produce symptoms of the disease this year; they are being kept under observation.

Small scale trials of commercial apple varieties worked on the apomictic species *Malus toringoides* and *Malus sikkimensis* have shown that trees on these two seedling stocks come into cropping as early as those on M.II and, with some varieties, the early crop weights are heavier. Of a wide range of apple varieties tested on these two stocks only Chisel Jersey has so far been found to be incompatible.

Cider and Perry Varieties.

Studies were continued on the pollination requirements of cider varieties and of the factors affecting self and cross fertility. The variety Michelin has been shown to be highly self-compatible in the "on" year, but self-incompatible in the "off" year. It has also been shown that the nitrogen status of the pollen source is an important factor in fruit set, at least in some varieties of apple. In studies with Laxton's Superb, Worcester Pearmain and Michelin it was

found that pollen from trees deficient in nitrogen, although it germinated well *in vitro*, was markedly inferior in its capacity to bring about fertilization and fruit set as compared with pollen from high nitrogen trees. Studies of fruit set and seed content of fruits at different distances from a pollen source again gave a figure of about 90 ft. as the maximum effective distance of a pollinating source, an estimate similar to that obtained in 1956.

Work on the description of cider and perry varieties was continued and further descriptions of perry varieties will be published shortly.

Following a request from the Cider Advisory Committee for recommendations on the headworking of orchard trees, a survey was made of 18 farms in Somerset and Gloucestershire in which extensive headworking had been carried out. In only a few instances was headworking an unqualified success. Many of the headworked trees were showing apple mosaic and other virus-like symptoms, suggesting that the trees on which they were worked were carriers of these viruses. Many of the trees in the cider scion nursery at Long Ashton have now been indexed on Lord Lambourne, and several varieties have been found to be carrying either rubbery wood, apple mosaic, or both. A search is now being made for virus-free sources of these varieties to replace the present trees.

Plant Nutrition : Fruit.

Field Experiments.

The striking differences reported in 1956 in the growth and leaf nutrient status of the young apples in the cover-crop trial at Long Ashton (Plot 18) were maintained during the past season. Tree growth and leaf nitrogen status were normal on the clover and "tumble down" (natural sward) plots, but trees on timothy and rye grass plots were stunted and suffered from severe nitrogen deficiency. Fruit set was clearly related to nitrogen status, ranging from nil to slight on the rye and timothy plots, and good to heavy on the "tumble down" and clover plots.

Trees on the apple cover-crop-manurial experiment at Efford, and the plum cover-crop-manurial experiment at Luddington, continued to make satisfactory growth.

A new pear cover-crop-manurial experiment has been started this year at Long Ashton (Plot 7) using two-year-old trees of the varieties Conference, Williams and Comice.

Field work with iron chelates, for the control of lime-induced chlorosis in pears, was continued in the Evesham area. Chlorotic trees given sub-soil injections of 20 g. Fe per tree as Ferro Versenol (Fe-HEEDTA (N-hydroxy-ethylethylenediaminetriacetic acid)) in 1956 continued to make normal growth in 1957. Surface soil applications of 1 g. Fe per tree as Chel-138 (Fe-EDHPA (ethylenediamine bis (o-hydroxyphenylacetic acid))), and 2 g. Fe per tree as Fe-CDTA (cyclohexane *trans* 1:2-diaminotetraacetic acid), applied in late July 1956, controlled chlorosis in that year and in 1957. Chel-138 is particularly stable in calcareous soils and is the most effective iron chelate so far tested under field conditions.

Seasonal control of chlorosis was again obtained from three consecutive foliar sprays of Fe-HEEDTA at 0.1% concentration + wetter, and from iron-lignin sulphonate at 0.5% of liquid concentrate. A new iron chelate (code number RA-157) was also very successful as a foliar spray when used at 0.1%

concentration + wetter. Residual effects were noted in 1957 on trees sprayed in 1956 with Chel-138 and Fe-CDTA at 0.1% concentration; no residual effects were noted on trees sprayed with other iron chelates.

The strawberry soil-conditioner trial at Efford, started in 1954, has been completed (p. 71). The strawberry nutritional experiment at Efford has been extended for a further season in the hope that treatment effects may be enhanced in the third cropping season.

Water supply has been a limiting factor in the black currant nutrition experiment at Luddington, and arrangements have been made for irrigation in future seasons. There has so far been little response to fertilizer treatments in the black currant nutrition experiments at Efford and Long Ashton.

Pot Experiments.

The first of a series of factorial sand culture experiments, designed to study the phosphorus requirements of strawberry, *var.* Talisman, by chemical analysis of leaf samples, was completed in 1957. Optimum growth and yield of fruit were associated with a leaf phosphorus status at fruiting of approximately 0.3%P in dry matter (all other nutrients being present in sufficient amounts). Further experiments were started with the variety Talisman to determine optimum leaf potassium status, and with the variety Royal Sovereign to determine whether it has the same phosphorus requirements as Talisman.

Preliminary experiments were carried out on the quantitative uptake of foliar-applied magnesium by young normal and magnesium-deficient apple trees. Over short periods the absorption was greater from the lower than from the upper leaf surface, and from deficient as compared with normal leaves; it was also affected by air temperature and rate of drying. Further experiments are contemplated in 1958, using controlled light and temperature conditions.

Laboratory Investigations.

Work on leaf analysis in relation to nutrient status was continued.

Modifications of the colorimetric Titan yellow method have been made for the determination of magnesium in plant material and soils; these include the removal of phosphate by passing the solution through an anion exchange column. The results obtained are more reproducible and accurate than those given by previous methods. Potassium and calcium may be determined directly in the eluate by flame photometry.

The properties of some chelating agents and their iron and calcium chelates have been investigated in detail. It was found that a large excess of calcium ions adversely affected the stability of most iron chelates. Those chelating agents containing phenolic ring structures, e.g. Chel-138 and RA.157, were least affected by excess calcium ions at high pH; these two compounds form weak calcium chelates but highly stable iron chelates and are therefore ideal for the treatment of lime-induced chlorosis by soil application.

The spectrophotometric method of analysis was extended to several new chelating agents, code numbers RA.155, 156, 157 and 159 and to ATA (ammonia-triacetic acid) and HEG (hydroxyethylglycine).

The behaviour of Fe-ATA, Fe-HEG and Fe-RA.155 (labelled with ^{59}Fe) in calcareous soil was investigated in collaboration with the Chemistry Section. Practically all the iron supplied as Fe-ATA or Fe-HEG was precipitated

almost immediately, whereas about 50% of the iron applied as Fe-RA. 155 (aliphatic structure) was still soluble after 15 days ; the rate of isotopic exchange from this chelate was also slow.

Chemistry.

Organic Chemistry.

Synthesis of 3-substituted-2-naphthyloxyacetic acids for investigations of the relationship of molecular structure and plant growth-regulating activity has continued. 3-Methyl-2-naphthol, previously inadequately described in the literature, has been synthesized from 2-hydroxy-3-naphthoic acid and the corresponding oxyacetic acid prepared for test. This was found to be highly active in the tomato ovary test in contrast to the 3-hydroxy- and 3-methoxy acids. 3-Nitro-2-naphthol, the only unknown mononitro-2-naphthol, has now been synthesized (77)*. It condenses with ethyl bromoacetate with great difficulty to form 3-nitro-2-naphthyloxyacetic acid, which was required in order to examine the effect of a strongly electron-attracting 3-substituent on biological activity. 3-Cyano-2-naphthyloxyacetic acid was prepared for test with a similar object in view. Various attempts to obtain 3-amino-2-naphthyl-oxyacetic acid from 3-amino-2-naphthol by condensation with ethyl bromoacetate gave only the ring-closed product 3:4-dihydro-3-oxo-(2':3'-naphtho)-1:4-oxazine. Attempts to prepare 3-methoxy-2-naphthyloxyacetic acid by methylation of the corresponding 3-hydroxy acid resulted in an analogous ring closure to 2-oxo-(2':3'-naphtho)-1:4-dioxan. It was eventually obtained by direct condensation using 3-methoxy-2-naphthol.

In order to confirm the role played by chelation in the fungicidal activity of 5-*n*-amyl-8-hydroxyquinoline, the isomeric 5-*n*-amyl-6-hydroxy-quinoline, which should possess comparable lipid solubility whilst being incapable of heavy metal chelation, was synthesized. When tested against the mycelium of *Aspergillus niger* van Tiegh it was found to be considerably less toxic than 5-*n*-amyl-8-hydroxyquinoline ; substitution of a nuclear chlorine atom in this latter molecule had little effect on toxicity.

Work on the metabolism of ω -(2-naphthyloxy)-*n*-alkylcarboxylic acids by *Sclerotinia laxa* has now been completed. Using a replacement culture technique, γ -(2-naphthyloxy)-*n*-butyric and δ -(2-naphthyloxy)-*n*-valeric acids were shown to undergo β -oxidation to the corresponding acetic and propionic acids respectively. Naphthol was isolated in small amounts from β -(2-naphthyloxy)-propionic acid, but nuclear hydroxylation by the fungus was virtually absent. The conversion of 2-methoxynaphthalene to 4-methoxysalicylic acid by *A. niger* is being investigated. A method for the preparation of certain substituted 2-carboxycinnamic acids, required for an investigation of possible metabolic pathways, has been accepted for publication.

A chromatographic examination of the resins from *Derris* and *Lonchocarpus* species, using a silica gel column, has shown the presence of a previously unreported compound. Structural investigations on this unknown are proceeding together with further work on the resins.

Physical Chemistry.

Radioactive tracer work with the isotopes ^{14}C , ^{32}P , ^{99}Mo , ^{59}Fe and ^{64}Cu has been carried out during the year. Two procedures have been developed

*See *Publications*, 1957, pp. 157-161.

for ^{14}C assays : (a) the combustion of material to carbon dioxide with subsequent quantitative precipitation as $\text{Ba}^{14}\text{CO}_3$ followed by end-window counting ; and (b) the use of a 4 Pi counter as designed by Winteringham to scan chromatograms and to radioassay deposits on filter paper. In collaboration with the Pomology Section, techniques for the extraction from plant tissues of growth-regulators labelled with ^{14}C have been developed (pp. 23-24).

In joint work with the Fruit Nutrition Section, the investigation of the behaviour of iron chelates in calcareous soils has been extended to include a further four chelates labelled with ^{59}Fe (p. 27). Work with the A.R.C. Unit on the distribution of iron and molybdenum in micro-organisms, using ^{59}Fe and ^{99}Mo , has continued while ^{32}P has been used to check the accuracy of methods for determining phosphorus in plant material.

The development of a reliable method for the determination of dynamic surface tensions of solutions containing surface-active agents has continued using a vibrating jet technique. The experimental procedure used by Addison has been replaced by a technique in which a parallel beam of monochromatic light is used to determine photographically the wavelength and profile of the jet. The validity of this method is being confirmed using pure liquids of known surface tension.

Studies have been made of the mechanism of action of fungicides. Chemical tests and radioassays of Burgundy mixture prepared from ^{64}Cu have shown that a significant amount of copper is sorbed from deposits by bean leaves and that this copper is fungicidally inactive (60). The evidence suggests that the copper is adsorbed on the surface rather than absorbed within the leaf. The movement within leaves of copper from surface deposits was found to be negligible. The effect of the surface treated on the fungitoxicity of captan and copper spray deposits has been determined using spore germination tests on glass slides and detached leaves.

Field experiments made in collaboration with the Plant Pathology Section have shown that the suppression of shoot infections of *Gloeosporium perennans* by phenyl mercury chloride is markedly improved by the addition of either linseed oil emulsion or a paint formulation of polyvinyl acetate.

A homologous series of n-alkyl thioethers of 2:5-dimercapto-1:3:4-thiadiazole, ranging from methyl to octyl, have been examined with reference to their solubility in water, oil-water partition coefficient, and uptake by both potato tissue and fungus spores. The compounds have been identified by their U.V. absorption spectra. Preliminary results have shown that the uptake of these compounds from aqueous solution by spores of *Monilinia fructicola* and *Stemphylium sarcinaeforme*, and by potato tissue, increases with increasing length of side chain and with decreasing pH of the solutions.

Analytical and General Chemistry.

Work has continued on physical and chemical methods for the examination of spray deposits.

The behaviour of DDT applied in suspension, emulsion or miscible oil formulation to leaves of various kinds has been followed by recovering the deposits, after varying intervals of time, in films of the synthetic adhesive Aerolite 306. Crystals from suspensions persisted on the leaf surfaces for appreciable periods, but few crystals were present in the dried deposits of the emulsion and miscible oil formulations used. The tests are of interest in

connection with the biological efficiency of DDT in different formulations and will be extended to other waxy and non-waxy leaf surfaces.

Chemical methods have been developed for the determination of DDT and chlorobenzilate occurring together in spray deposits. Special attention has been given to mercury deposits in view of possible consumer hazards, and an analytical technique has been evolved to avoid the risk of loss of mercury in the normal method involving acid digestion. Surface and absorbed deposits were recovered by solvent extraction, and interference was removed by chromatographic separation on a column of cellulose (p. 76). The chemistry of dieldrin and endrin has been studied with a view to the development of a colorimetric method of assay. A new colour reaction of satisfactory sensitivity has been obtained for dieldrin, but further work is required to reduce the blank values on reagents. Further investigation has been made of the influence of ammonium ion on the determination of copper with bis-*cyclohexanone* oxalyldihydrazone. Rapid development of colour at pH values above 9.5 has been achieved only in the presence of a high concentration of ammonia.

The methods now available have been used to assess spray deposits in field trials. The method for sulphur described in the last Report has been utilized in comparisons of the deposits of lime sulphur resulting from different methods of application in work on the control of apple scab. Captan deposits were determined on strawberries treated for the control of grey mould. Mercury deposits from repeated spraying of Bramley leaves and fruits with phenylmercuric nitrate were determined throughout the season: surface deposits were markedly reduced between each application; some accumulation of mercury occurred in the leaves, and fruits at harvest each contained some 10 micrograms of mercury distributed between the peel and flesh (p. 76). Tests were also made of the persistence of mercury on treated cankers. The micro method for DDT described last year has been used to determine deposits on apple and pear buds and leaves from different methods of application, on twigs in work on caterpillar control and on coconut leaves and spadices from spraying trials by the Entomology Section overseas. Analytical work was carried out to follow the persistence of DDT and a fluorescent tracer material applied together, and to compare the deposits of DDT, copper and mercury obtained on different leaf surfaces under different wetting conditions.

A re-examination has been made of the method for determining rotenone in derris and barbasco roots. The separation of phenolic constituents of the resin before the formation of the rotenone-carbon tetrachloride complex has given values higher than those obtained by the standard method. An alternative analytical procedure has been submitted for examination by a joint committee of the Pharmaceutical Society and the Society for Analytical Chemistry.

Work on plant waxes has continued. The waxy coverings of leaves of broad bean, dwarf bean, pea, cabbage, laurel, tomato and pear and of fruits of gooseberry, tomato and apple have been examined, and their contents of true wax, oil, volatile and acidic components determined. Fluctuations in the composition of Worcester and Cox leaf waxes were followed throughout the season. An investigation was made in collaboration with the East Malling Research Station of the effect of the nutritional status of Cox apple trees upon the amount and nature of the wax formed on the fruits.

Work on the fungistatic properties of components of plant waxes was extended to two varieties of tomato that show a marked difference in

susceptibility to leaf mould ; the ether-soluble acidic components of the small amount of wax formed by the leaves inhibited the germination of spores of *Cladosporium*. The water-soluble acids found in association with leaf waxes were found to solubilize copper from Burgundy deposits, showing the contribution made by the host plant to the toxic action of the fungicide (41).

Collaborative work with other organizations has continued. Determinations of DDT in soil samples were made for the National Vegetable Research Station, and work with the Infestation Control Division of the Ministry of Agriculture, Fisheries and Food on the determination of DDT in grain was completed.

Entomology.

Biology of Insect Pests.

Population studies of Oat Apple aphid (*Rhopalosiphum insertum* Wlk.), Rosy Apple aphid (*Sappaphis plantaginea* Pass.) and Woolly aphid (*Eriosoma lanigerum* Hsmnn.) were continued. The autumn migrants of the first two species return from the host plants to the apple about the middle of September, and the oviparous forms reach a maximum in late October and early November. The intensity of aphid attack on different varieties of apple in spring may be related to the number of migrant aphids attracted to the autumnal leaves.

The primary leaf curling caused by *S. plantaginea* is the result of feeding punctures in the young petioles. While this damage may not in itself be of major importance, the curled leaves protect the aphids against inefficiently applied sprays so that colonies may increase rapidly and cause serious damage to fruitlets and new shoot growth. It was confirmed that efficiently applied BHC emulsion is able to control the aphids completely, even after initial leaf curling has occurred.

The migration of young Woolly aphids from overwintering colonies started in early May in 1957 and reached a peak in mid-July ; after this there was a rapid reduction in the size of the colonies because of predation by Coccinellids.

Preliminary observations on the Leaf Hoppers infesting apples at Long Ashton show that the two main species are *Typhlocyba debilis* and *T. froggatti* but further analysis of samples is needed to determine their relative importance and whether other species are involved.

Work on the transmission of Brown Rot of apples by insects was carried out in co-operation with the Plant Pathology Section. Records of insects visiting fruit were made. The most frequent visitors were found to be *Calliphoridae* and *Vespidae*. When the rotting fruits were sprayed with either griseofulvin, di-butyl phthalate or a mixture of the two, the number of insects visiting the fruits was reduced. This seemed to be due to the sprayed fruits being rendered drier and less attractive rather than to a direct repellent action of the spray materials.

Bio-assays of insecticides and fungicides.

In further work on the effects of insecticides on the respiration of the cockroach, *Periplaneta americana*, the effects of carbon dioxide, light and starvation on the adult and nymph have also been studied. A respirometer for the accurate measurement of small gas changes within small time intervals is being developed.

In studies of the biological efficiency of fungicide spray deposits on leaf surfaces it was shown that the absence of free surface water at the time of germination and infection greatly reduced the range of action of copper spray deposits. Lime sulphur deposits, on the other hand, maintained their range of action under these conditions. The copper fungicide distribution required to prevent infection by spores arriving on an apparently dry leaf surface is more critical than that required to prevent infection in the presence of liquid water.

The simple suction apparatus devised for the uniform application of dry *Botrytis fabae* spores to leaf and other surfaces has been successfully used for *Cladosporium fulvum* spores in tests of the fungicidal action of leaf waxes carried out by the Chemistry Section.

The toxicity of DDT deposits on apple shoots to the larvae of the Winter Moth (*Operophtera brumata*) was investigated. First and second instar larvae died after crawling $\frac{1}{2}$ " on bark covered with a deposit of approximately 4 μ g. per sq. cm. The third instar became irritated and fell off the wood after walking 14-21", and subsequently died with typical symptoms of DDT poisoning. The fourth instar walked about 36" with similar results. These experiments will be continued to ascertain the behaviour of the larvae on opening flowering buds. The DDT deposit was obtained from a naphtha-sulphite lye emulsion containing 0.025 per cent. technical DDT with 0.025 per cent. nonyl di-sodium sulphosuccinate wetter added to give complete wetting of the bark.

Malathion at 0.025 per cent. strength, prepared as an emulsion of high wetting properties, was found superior to *gamma* BHC in field trials for the control of the Leaf Curling Apple aphid and the Cherry aphid, particularly in well established infestations. Its value as an aphicide on black currants is under investigation as it may well avoid the risks of fruit taint reported to result from the application of *gamma* BHC. Tasting trials for the detection of taints from BHC and malathion sprays on black currants are under investigation by the Domestic Food Preservation Section. There is no evidence to date of a taint developing from the application of normal strengths of *gamma* BHC at the "grape cluster" stage.

Spray Techniques.

The study of the incorporation of surface-active agents as spray supplements has been continued. Work on the phytotoxicity of wetting agents to varieties of apples and plums has been extended to cover some 70 different materials that may be used as wetters, emulsifiers or penetrants in spray formulations. The chemical nature of all the materials used was well established so that it is possible to relate variation in phytotoxicity with variation in chemical structure of the surface-active agent. Whilst it will take some time to correlate all the results obtained, certain conclusions appear fairly obvious: non-ionic surface-active agents are far less toxic than their ionic counterparts; phytotoxicity is not directly related with wetting ability, and there appears to be a relation between the physical size of the surface-active agent molecule and the degree of phytotoxicity. Climatic conditions appear to be of only secondary importance.

Investigations into possible reactions taking place between surface-active agents and leaf surfaces show that cationic materials are adsorbed very strongly and, once adsorbed, are very difficult to remove from the leaf surfaces. This behaviour is very different from that shown by anionic materials and would

indicate a greater deposition of active ingredient (insecticide etc.) on a plant surface from cationic emulsions than from anionic emulsions.

Some work has been started on the deposition on leaf surfaces of the oil phase of various emulsions. Preliminary results indicate that the physical nature of the emulsion itself is quite as important as the chemical nature of the formulation employed. This considerably complicates the direct comparison of deposits obtained from emulsions of different formulations since it necessitates a complete analysis of the oil droplet size in the emulsion under test, as well as a chemical analysis of the deposit obtained from the emulsion.

The production of spray droplets and their trajectories and impaction are now being studied, using a form of the vibrating reed sprayer.

Field trials with wetters showed that an alkyl aryl polyethyl alcohol, a non-ionic wetter, is satisfactory on all fruit crops when used at 0.025%. It is compatible with all spray materials normally used. Preliminary experiments have shown that the formulation of emulsions of high wetting properties can be modified to increase the initial retention of the toxicant: the deposit of DDT on apple leaves was increased from 2 to 8 $\mu\text{g.}$ per sq. cm.

Laboratory and field investigations were carried out on the value of fluorescent materials as tracers in insecticide formulations; Saturn Yellow was found a satisfactory material in emulsions. A photographic technique was developed for recording results; it appears to provide a valuable qualitative method for rapid determinations of deposits of spray materials.

Field experiments on the control of apple aphids at the "mouse-ear" and "green cluster" stages by large and small volume spraying techniques, using dilute DDT/BHC emulsions (0.05% DDT, 0.0125% BHC) and wetting agent, showed that large volume hand spraying at 400 gall. per acre was superior to small volume air-flow mist spraying at 112 and 60 gall. per acre. Measurements of the DDT deposited suggest that control of the aphids at the green cluster stage depends on the deposition of certain minimum quantities of insecticide at the correct site on the flower buds; insecticide deposited on the leaves has little effect at this stage. Efficient large volume hand spraying ensured effective deposition on a greater number of clusters than did the small volume air-flow method.

Experimental spray materials were supplied to Kenya and the British Solomons for investigations on the control of *Pseudotheraptus* and *Amblypelta* Nutfall Bugs of coconuts respectively. Laboratory, field and spray equipment was also dispatched to North Borneo to enable a member of the Long Ashton staff to undertake an investigation of spraying techniques on *Abaca* hemp.

Techniques have been developed for the extraction of DDT from plant tissues of tropical crops, so that samples can be sent by air freight to the U.K. for accurate assay, and for the transport of plant tissues sprayed with copper fungicides. The Chemistry Section has taken an active part in this work.

Spray Machinery.

A small 70 c.c. compressed air sprayer was designed for laboratory work on the application of small droplets of highly concentrated materials to the spadices of coconuts. One machine was supplied to the British Solomons.

In a search for reliable and simple methods of atomising liquids into small droplets of uniform size, a number of attempts have been made to produce droplets of about 80 microns by using low-pressure air nozzles. While uniformity

has been greatly improved it has not yet been possible to reduce droplet diameter to the required size (p. 123) : this work continues.

Plant Pathology.

Further work on resistance to brown rot (*Sclerotinia fructigena*) showed that oxidised *l*-epicatechin, one of the phenolic components of apple fruits, was particularly effective in suppressing fungal pectolytic enzyme activity. Spray applications of griseofulvin (0.1% active material) temporarily reduced the infectibility of artificially-made apple wounds.

Gloeosporium perennans produced its ascospore stage (*Neofabraea mali-corticis*) on shoots of apple which were inoculated in the autumn, detached after 2 months and then kept in the open for 9 months. The relation between the two stages was confirmed by ascospore inoculations into shoots and fruits.

The susceptibility of pruning cuts to *Gloeosporium* infection was shown to be influenced by the position of the wound, the age of the wood and the seasonal changes in host resistance. Fungicide trials on *Gloeosporium* cankers showed that 0.3% phenyl mercury chloride in a 2% linseed oil emulsion spray applied in March gave 75% reduction in the production of viable spores up to October (p. 105).

In preliminary germination trials on leaves, conidia of the apple scab fungus (*Venturia inaequalis*) gave a higher percentage germination and more rapid germ-tube growth than ascospores : conidia of *V. pirina* (pear scab) showed more rapid germ-tube growth than those of *V. inaequalis* (p. 97).

Further studies of bud infection by apple mildew (*Podosphaera leucotricha*) demonstrated the prolonged period of susceptibility of the terminal buds. Field trials on Cox's O.P. showed that two post-blossom sprays with 1% lime sulphur reduced over-wintering Fruit bud infections to 1% or less, compared with 6% on trees left unsprayed, or sprayed pre-blossom only (p. 114).

In a mildew control trial on Leveller gooseberries at Efford Experimental Horticulture Station the percentages of mildewed fruit after the respective spray treatments were : Karathane 0.3% ; washing soda and soap 1.1% ; unsprayed 5.2%. No spray damage occurred.

Ascospores of the black currant leaf spot fungus (*Pseudopeziza ribis*) were shown to infect red currant and gooseberry leaves, and ascospores of *P. ribis* from gooseberry were also found to infect leaves of black and red currant.

Cultures of *Sclerotinia laxa*, *Botrytis cinerea* and *Aspergillus niger* were grown in the presence of a concentration of captan that caused approximately 50% reduction in growth. Assays made on homogenates of the resulting mycelial felts showed that while their catalase content was increased there was little effect on nitrate and nitrite reductases, acid and alkaline phosphatases and carboxylase.

In tests made (in collaboration with Organic Chemistry) on the fungistatic activity of a series of 5-*n*-alkyl-8-hydroxyquinolines against mycelium of *Aspergillus niger*, it was found that activity of the non-chelated molecules rose to a maximum at a chain length of 5-6 carbon atoms. This was due more to greater uptake of these homologues than to their higher inherent toxicity. In the presence of metals, however, fungistatic activity declined rapidly as the series was ascended.

A. niger was shown to break down 2-methoxy-naphthalene to 2-hydroxy-4-methoxybenzoic acid, and 2-ethoxynaphthalene to the more fungistatic 2-hydroxy-4-ethoxybenzoic acid.

Cider and Fruit Juices.

Cider.

Chemical and microbiological studies of apple juices and cider fermentations have continued. Work on amino acids (8,9) has been followed by investigations of proteins, purines and related nitrogenous compounds. Methods suitable for their isolation from juices and ciders have been investigated; chromatographic techniques have shown the presence in apple juices of traces of adenine and tentatively of uracil and guanine.

Further work on organic acids has involved the development of improved methods for their separation and quantitative estimation, using silica gel columns; chlorogenic acid has been isolated by this technique. Examination of the other organic acid fractions has shown the presence of α -ketoglutaric acid in juices and ciders. Two other acids, previously difficult to separate from citramalic acid, have now been identified in sulphited ciders, viz., α -hydroxyglutaric acid and 2-methyl-2:3-dihydroxybutyric acid. The latter compound has not previously been isolated from natural sources but has been postulated as a precursor of the amino-acid valine. Both acids may have been present in the apple juice before fermentation.

The effects of fruit maturity on juice composition have also been studied. During growth on the tree there was a decrease in the amounts of chlorogenic and quinic acids present in the juice. Juices pressed from fruit stored after harvest showed a fall in acidity with increasing maturity, the fall being mainly in malic acid. Citramalic acid, the main acid of the peel, increased during prolonged fruit storage. Juices pressed from over-mature fruit contained an increased amount of protein nitrogen; the amounts of amino acids and other components showed little change. The main effects of over-maturity were increased difficulties in juice pressing, a low yield of juice and an over-all loss of sugar.

The numerous isolates of yeasts obtained from fruit, juices and ciders have now been classified: they include several new species. The occurrence of the different species has been followed throughout the process of cider-making. It has been shown that the flora present in small scale experimental fermentations corresponds to that of the fruit whereas the yeasts present in juices and ciders made under factory conditions are largely derived from the equipment.

The effects of sulphite treatment on the juice and cider flora during the different stages of cider-making have been studied in more detail. It has been confirmed that this treatment, whereby the lactic acid bacteria are suppressed and the fermenting yeasts encouraged, is advantageous for low-acid juices. The effect persists throughout fermentation; the resulting ciders are free from harmful bacteria and thus remain more stable on storage. In ciders from untreated juices bacteria may predominate, and the use of the centrifuge to clarify such low-acid ciders may aggravate the situation.

Earlier work on lactic acid bacteria has been published (16) and attention has been mainly confined to studies of their nutrition and metabolism.

It has been confirmed that certain species hydrolyse the chlorogenic acid of apple juices to quinic and caffeic acids, quinic acid being reduced to dihydroshikimic acid (17) and caffeic acid converted to dihydrocaffeic acid and ethyl catechol (72).

A survey of acetic acid bacteria present on fruit, and in juice and cider, has revealed that a range of species may be present. On fruit the organisms were found associated with soil contamination. Acetic bacteria were found present throughout both aerobic and anaerobic cider fermentations but the distribution of species differed. Under conditions of low oxygen tension, as during active fermentation, species of the Suboxydans group, which oxidise ethanol only to acetic acid, predominated. In contrast, members of the other groups, which are able to oxidise acetic acid also, were present in greater numbers in dry ciders and on cider-making equipment. The metabolism of the acetic bacteria is now being studied in relation to the production of cider vinegar.

An investigation of pectin changes in cider fermentations has been undertaken in view of problems associated with the fermentation of pasteurised juices and concentrates. In cider fermentations as normally carried out it has now been shown that pectin is effectively removed by the fruit pectin-methylesterase acting alone or in conjunction with polygalacturonase produced by certain members of the natural yeast flora. It has now been demonstrated that yeast polygalacturonase is commonly present in ciders. In the fermentation of juices that have been subjected to heat treatments and subsequently yeasted this mechanism for pectin breakdown may be absent or incomplete, thus leading to difficulties in cider clarification.

Unfermented juice products.

Work on fruit juice processing has largely been concerned with problems of pectin breakdown in fruits and juices and has been studied in conjunction with the work on pectin changes during fermentation. The polygalacturonase produced by cider yeasts has been studied and the possible application of yeast enzymes in juice processing has been considered.

The reactions of copper occurring naturally or as a contaminant in fruit juices have been further investigated and additional fundamental data have been obtained (31,66,67). The dissociation constants of catechol have been determined potentiometrically, also the equilibrium constants of the copper-catechol reactions and the stability constants of the complexes: polarographic measurements have confirmed the potentiometric data. This work has now been published (68). The complexing of copper with apple juice phenolics in isolated systems is now being similarly studied and it is evident that the carboxyl groups of phenolic acids, as well as the hydroxyl groups, can take part in complexing reactions.

Work on complexes between copper and organic acids has also continued and polarography is being used to study fruit juice systems themselves. The study of copper-catalysed oxidations in black currant and other fruit juices is also being investigated.

Domestic Food Preservation.

Further investigations on the processing times required for bottled meat products have been made for inclusion in a new bulletin on domestic meat and poultry preservation to be published by the Central Office of Information.

The final script was submitted in May, after its approval by the authorities concerned. Accounts of the microbiological and heat-penetration studies entailed in assessing the safety of the various meat processes in different kinds of container have also been prepared for publication.

Further tests on the quality of bacon preserved by freezing or by the traditional methods of cool storage have shown the superiority of the frozen product for long storage. The results are described in this Report (p. 137).

Studies on the growth of heat-resistant bacteria and the rates of heat-penetration in different packs of vegetables have been continued in order to check the safety limits of the established methods and to formulate processes for vegetables not at present included in Ministry publications.

Eighty-eight varieties of fruit have been examined for fresh fruit quality and have been preserved by different methods. These include 44 gooseberry varieties grown by the Pomology Section, 13 raspberry and 13 strawberry varieties grown at Starcross, Devon, and 10 blueberry varieties from trial plots at Wareham.

Thirty-nine varieties of vegetables have been tested for preserving quality. The amount of waste during preparation has been noted and the ascorbic acid content determined in the fresh vegetables and again after scalding prior to preserving. The canned vegetables are being tested for quality and loss of ascorbic acid content during storage, but the breakdown of a deepfreeze cabinet has meant the postponement of comparisons with the frozen varieties.

Tasting trials for the detection of taints caused by spray treatments in fresh and preserved fruits have included tests on strawberries sprayed with captan or thiram and black currants sprayed with malathion, BHC (Lindane) and captan in different concentrations. Further samples are being tested after more prolonged storage.

The suitability of different covers for use with pickles and chutneys has been assessed by comparing the losses of acetic acid through evaporation during storage. Tests have also been made of the efficacy of covers in preventing the entry of moulds on jam.

Preliminary trials are being made with a new type of equipment for the extraction of fruit juices.

The preparation of a new edition of Bulletin 21, *Domestic Preservation of Fruit and Vegetables*, has necessitated the testing of a number of recipes and the revision of the section on crystallized fruits.

Willows.

Variety Collection.

The study of varietal characteristics has been continued. Cuttings of the so-called *Salix aquatica gigantea*, Clone 56, were obtained from Finnish and German sources, and two unidentified fast-growing hybrids were received from Northern Ireland, bringing the total number of varieties in the collection to 182.

Experimental Work.

Assessment was again made of the root pattern of basket willows planted at Long Ashton in 1954. The proportion of roots found in the surface 3" was 23.1% compared with 14.5% in 1956, whilst at a depth of 3"-6" the proportion

was 32.1% compared with 40.0% in 1956. The root system consisted essentially of horizontal laterals : only rarely were strong vertical roots produced from the base of the cutting. The mean length of the longest root per stool was 67 inches ; its mean depth below the surface was $5\frac{3}{4}$ inches.

Experiments to investigate the use of 2:4-D and 2:4:5-TB as selective weed killers in willow beds were made in collaboration with the Entomology Section, using a pressurized knapsack sprayer and a lance designed to apply 40 gall. per acre at a walking pace of $2\frac{1}{2}$ m.p.h. over an inter-row swath adjustable from 10" to 18". 2:4-D applied at 3,700 p.p.m. to a mature willow bed in July gave good control of nettle, Meadow Sweet, Silverweed and Purple Loosestrife : 2:4:5-TB applied at 3,900 p.p.m. was effective only against Silverweed. In a bed newly planted in 1957 one application of 2:4-D at 3,700 p.p.m. completely destroyed the ground vegetation of prostrate vines of Greater Bindweed within five weeks : 2:4:5-TB at 3,900 p.p.m. had the same effect after seven weeks. No damage to the willows occurred in these experiments.

2:4:5-TB at 500, 1,000 and 1,500 p.p.m. was applied to run-off to erect willow rods 4 ft. tall, entwined with Greater Bindweed. In all treatments the aerial stems of the Bindweed were killed within seven weeks and damage was sustained by the rhizomes to a depth of 3"-4". The willows were damaged by 1,500 p.p.m., very slightly by 1,000 p.p.m. and not at all by 500 p.p.m.

In collaboration with the N.A.A.S., a number of fungicides were tested in June and July for the control of willow rust, *Melampsora amygdalina*. Weights per 100 gall. were : colloidal sulphur 3 lb. ; Zineb 2 lb. ; Fernide 2 lb. ; Perenox 3 lb. ; Karathane 1 lb. ; calcium sulphamate 1 lb. ; captan 2 lb. Applications were made on June 6, June 20 and July 4, when the lengths of the willow shoots were 2.9", 10.9" and 23.7" respectively. Calcium sulphamate proved to be very phytotoxic, and only Perenox gave a significant reduction in the amount of rust infection. Further investigations of the early stages of rust infection are being made.

The sale of 55 cricket bat willows has enabled more information to be obtained on the costs of conversion and utilization, and also on the relationship between the appearance of the tree and the quality of its timber. Advanced stages of attack by *Armillaria*, indicated by dead branches, sporophores, rhizomorphs and loose bark, rendered some of the trees useless. Less noticeable attacks, indicated only by a few dead branches, were also damaging, since a yellow brown discoloration just below the bark extended from the root buttresses to a height of at least 10'. This discoloration reduces the timber to its lowest value. The trees were 28 years old and had been planted 30' apart. Planting distances of at least 40' are now being recommended (p. 143).

Advisory Work.

There were 233 requests for information during the year. 50 visits to growers were made as below :—

	South West	Home Counties	East Anglia	Midlands	North	Wales	Foreign
No. of enquiries	69	62	24	17	21	20	20
No. of visits	37	5	2	1	—	1	4

Two-thirds of the enquiries were concerned with basket willows and one-third with bat willows.

There were 15 requests for planting material which included two from research and four from educational centres. The range of sites at which willows are grown experimentally has been increased by the inclusion of coastal sites in Northumberland and Suffolk.

Advice was sought by the Prison Commission on the possibility of planting an area in Suffolk flooded by the sea in 1953. Material sufficient to plant $1\frac{1}{2}$ acres was supplied in the spring, when the concentration of common salt throughout the surface 18" of soil had fallen to 0.04%. Growth this season has been satisfactory and a further $3\frac{1}{2}$ acres will be planted in 1958. The Commission hope that this area will supply the greater part of their requirement of basket willows; it will also provide information on the salt tolerance of basket willows and reliable data on the cost of establishing and maintaining willow beds.

Basket willows are no longer in such short supply, because of a reduction in Government contracts for baskets, and of international agreements which have enabled the economic importation of foreign willows of high quality. 1957 has been a very good growing season and the supply of home grown willows should equal the demand. 20 acres were planted in Somerset during 1957, giving a total of 1,347 acres in the county. Growers are making increased use of small power tools for weed control and of oil-fired plant for processing.

Serious outbreaks of the willow rust, *Melampsora amygdalina*, occurred in Somerset in the early summer. The willow weevil, *Cryptorrhynchus lapathi*, has again damaged both young and old beds; the life cycle and the control of this pest will be studied during 1958.

Further investigations of the use of willows for paper pulp have included trials of cricket bat timber. The newly imported variety *Salix aquatica gigantea*, Clone 56, is reputed to have been bred for the production of paper pulp. Its rate of growth this season does not suggest that it will prove suitable for economic pulp production in Great Britain.

Statistics.

Experimental Design and Analysis.

As in previous years, a large part of the Section's work has consisted of the design of experiments and analysis of results for the Station, for the Horticultural Science Laboratories and for other University Departments.

In the design of a cider variety trial in Herefordshire, a technique of restricted randomisation has been used to minimise the risk of intermixing of crop from adjacent trees, and so to improve the reliability of crop records. The varieties were grouped into two sets, each set including a well-known variety as "control"; precise comparisons of crop weights will be possible within each set. A perry pear rootstock and stem-builder trial has been designed and laid out at Long Ashton on Plot 7, adjacent to a new dessert pear plot for which plans had been prepared previously.

Many of the pyramid trees on Plots 13 and 16 became usable for the first time in 1957, and a number of experiments have been designed for these, including spraying, pruning and virus transmission trials. A layout has been prepared for the planting of a rootstock trial of "pillar" trees of two varieties.

Short-term trials for the 1957 season were planned for some Station plots and for outside sites at which members of Station staff were working. A considerable amount of laboratory and greenhouse work has again been designed and analysed statistically.

The examination (in collaboration with Entomology) of the possibility of expressing mathematically the shapes of droplets moving on an inclined plane has led to consultation with the Statistics Department of Rothamsted Experimental Station, in order to carry out calculations on the electronic computing machine. The accuracy of various stages in the process of measuring a drop is being examined.

Biometric Studies.

Collaboration has continued with the Domestic Food Preservation Section upon the design of tasting trials and the methods of assessment of samples of fruit by members of tasting panels. Similar sets of samples have been scored in various ways, but no outstandingly good method of assessment has yet appeared. Results of "triangular" taste-tests confirm the findings of other workers that the order of arrangement of samples within the triangles influences the reliability of results.

A study was planned for the Fruit Nutrition Section to enable components of variance to be estimated for successive sampling stages (field, biological, analytical) in chemical leaf-analysis.

The method previously published (Annual Report for 1955) has been used in collaboration with the Plant Pathology Section to obtain an index of varietal susceptibility to black currant leaf-spot, and it is planned to repeat this on a larger scale in 1958 to provide data of value to the Plant Breeder.

AGRICULTURAL RESEARCH COUNCIL UNIT OF PLANT NUTRITION (MICRO-NUTRIENTS).

Plant Physiology.

Molybdenum nutrition of higher plants.

The study of nitrate reductase activity in plants was continued. White mustard (*Sinapis alba*) was found to possess the highest apparent activity of several species examined, and values were often three times those normally observed in cauliflower. Relative apparent activity was found to vary greatly between different species and between plants of different ages, and was sometimes nil. The reasons for such apparently low activities in plants that grow vigorously with nitrate as their nitrogen source are being studied. The adaptive effects of nitrate and nitrite on nitrate reductase formation have been confirmed in mustard, where they appear greatly to exceed those already reported for cauliflower.

Factors affecting the precision of nitrate reductase assays required to demonstrate adaptive synthesis have been investigated. Interference by reduced pyridine nucleotides, reported previously, greatly decreases the sensitivity of the assay. Removal of reduced diphosphopyridine nucleotide used in systems derived from higher plants may be achieved enzymically. This method avoids the loss of nitrite which has been observed to occur in the presence of zinc or barium phosphate produced in other procedures when phosphate buffers are present, and ensures the use of minimal volumes for colour measurement.

Interference by adsorption of nitrite or the coloured diazonium compound on precipitated protein is avoided by the addition of sodium dodecylsulphate before the acid sulphanilamide reagent. Chilling tissues for periods of 30 minutes to 6 hours at -18°C before extraction was observed to produce 50–100 per cent increases in apparent activity compared with that in unchilled tissues, but this treatment totally destroyed the activity observed in leaf sections that were not ground to break the cells.

Molybdenum-deficient tomato plants grown in water cultures with ammonium sulphate as a nitrogen source showed symptoms of interveinal chlorosis in young leaves, which has not been described previously under these circumstances and differed from symptoms normally observed with known mineral deficiencies. There were, however, no notable decreases in protein, or total chlorophyll concentrations, or leaf primordia production rate as a result of molybdenum deficiency, but ascorbic acid concentration was decreased. Plants grown with nitrate showed typically severe symptoms of molybdenum deficiency. Growth and leaf primordia production were decreased as well as the concentrations of chlorophyll and ascorbic acid. Growth with ammonium sulphate was inferior to that produced with nitrate in the presence of molybdenum.

The microscopical examination of tissues of cauliflower affected by Whiptail was continued. Several technical problems have required attention, including the investigation of fixatives, adhesives and embedding methods suitable for use with a variety of stains and histochemical methods applied to the study of cell wall composition. Sections cut after freezing leaf areas showing the first signs of Whiptail have not so far revealed obvious anatomical differences from adjacent apparently healthy areas. Changes observed in cells of tissues showing more advanced stages of breakdown include the production of secondary meristematic development adjacent to areas of cell collapse in leaf mesophyll, the apparent proliferation of cells in the epidermal region and the infiltration of intercellular spaces in vascular tissues. The associated chemical changes have not been identified.

The study of phosphorus fractions undertaken in relation to effects of molybdenum nutrition has progressed with respect to analytical procedures to be employed. The determination of "acid-labile" phosphorus fractions in plant extracts has been facilitated by the observation that pigments which interfere with the estimation of the phosphomolybdic complex after 7-minute acid hydrolysis are removed by preliminary extraction with isobutanol before the estimation of inorganic phosphate. A fractionation procedure for the separation of major phosphorus components in leaves has been developed by modification of published methods. Leaves are killed and macerated in boiling alcohol. The alcohol-soluble constituents are separately fractionated by ether or petroleum ether extraction to give approximately 60 per cent. lipid and 40 per cent. non-lipoid compounds. The insoluble residue is extracted with 0.2 N hydrochloric acid which yields over 90 per cent. of the inorganic phosphorus and about half the phosphate ester fraction. The residue is extracted serially with N perchloric acid for 18 hours at 4°C , 0.5 N perchloric acid for 20 minutes at 70°C and finally with 2 N sodium hydroxide to yield RNA and DNA fractions with clear absorption maxima at about 260 $\text{m}\mu$., and phospho-protein. The final residue contains less than 0.3 per cent. of the initial total phosphorus, and results are reproducible for tomato leaves. Improved solvent systems for

two-dimensional paper chromatography of phosphate esters have been devised. The substitution of formic for acetic acid in an ethyl acetate system has given improved separation of several compounds; it also facilitates the drying of papers prior to the use of solvents containing ammonia. The inclusion of boric acid in these ammonia-alcohol solvents has led to greatly improved separation of hexose phosphates. Conditions for reproducible separations dependent on complete complex formation between borate and the phosphate ester are being investigated.

Aldehyde oxidase in potato. Some progress in the fractionation of the enzyme has been made by chromatography on a calcium phosphate gel column. One major fraction possessing aldehyde oxidase properties appears to be present: sharp separations can be obtained; specific activity is increased up to 15 times by this procedure and yields attain 40 per cent. of the total activity. Initial gel column chromatography has also been successful in eliminating serious interference by dark pigments which prevented the study of absorption spectra. Work is in progress to obtain preparations of relatively high specific activity before further investigation of the properties of the enzyme.

Tissue Cultures.

Attempts to produce root tip inocula capable of vigorous growth for prolonged periods were continued. Roots of sixteen species from five dicotyledonous and three monocotyledonous families were isolated and their suitability for culture tested in sterile media known to be satisfactory for roots of *Lycopersicon esculentum*. Roots of none of these species grew so vigorously as those of tomato, and most failed to grow. In others, the decline in vigour evident during the first passage was more rapid in successive passages and was accompanied by a rapid decrease in the number of surviving roots. Maintenance of vigour could not be achieved by the culture of tip and sector portions alternately, as practised in the continued culture of a clone of tomato roots. Variations in the organic supplements in the standard media produced no marked increase in the growth capabilities of the roots tested.

Excised tomato roots were used to test the possible side-effects of the methods used for purifying media for micro-element deficiency studies. The use of media purified by various standard methods did not apparently interfere with the growth of excised roots when the full complement of known micronutrients was given. An initial pH of 4.8 was optimal, but the alkaline drift during growth reduced the growth rate after six days. Ferric citrate was superior, as a source of iron, to the ferric sodium complex of ethylenediaminetetraacetic acid, which appeared to be slightly toxic.

Techniques were devised for the production of callus tissues from stem segments and root storage tissues, and attempts were made to subculture the isolated callus on agar or liquid media. Growth on static cultures was very slow and the resulting mass of tissue was unsuitable for the proposed investigations. Apparatus is being made which will enable such tissues to be grown in conditions under which the cell mass will be bathed alternately in liquid medium and in air.

Analytical.

The spectrophotometric method for the micro estimation of ascorbic acid

in plant tissues (Report for 1955) has been extended to include dehydroascorbic acid by reduction of this compound with homocysteine in a separate aliquot. Preliminary results suggest that reduction with hydrogen sulphide can be used to obtain similar results in a single aliquot corresponding to 10 mg. of tissue. Results obtained spectrophotometrically by either method and by titration with 2:6-dichlorophenol-indophenol show good agreement.

Nutrition of Micro-organisms.

Nitrogen Metabolism in Neurospora crassa.

Nitrite reductase. This enzyme was further purified and shown to be a flavo-protein dependent on copper and iron for its activity and requiring reduced diphosphopyridine nucleotide (DPNH) as the electron donor. The enzyme, which is associated with particles in the cell, was stabilized in 10% w/v sucrose and rendered soluble with deoxycholate. The flavin constituent was identified by paper chromatography and paper electrophoresis as flavin adenine dinucleotide. The dissociation constant (K_m) of the purified enzyme- NO_2 complex was 1.5×10^{-3} moles NO_2 /litre. The inhibition of the enzyme by the reduction products is probably due to hyponitrite since the addition of hyponitrite to the enzyme inhibited its activity whereas hydroxylamine did not.

Fractionation of the enzyme showed that both iron and copper were concentrated in the purified fractions but neither could be removed from the protein by dialysis against a range of chelating agents. Cu_2Cl_2 served as an electron donor for the enzymic reduction of nitrite and added flavin had no effect on this part of the system. Pyridoxine (Vitamin B_6), magnesium and phosphate have been shown to be required for maximal enzyme activity: the enzyme is much reduced in amount in a *Neurospora* mutant deficient in pyridoxine.

Hydroxylamine Reductase. A twelve-fold purification of this enzyme has been made from the fungus. Its activity was retained for a longer time in 10% w/v sucrose solution than in a phosphate buffer (pH 7.5). The enzyme is a flavoprotein containing FAD and requiring DPNH as the electron donor. Its activity can be measured either by following DPNH oxidation in the presence of hydroxylamine or by the production of NH_3 in Conway Units. The dissociation constant (K_m) for the enzyme-hydroxylamine complex was 3×10^{-3} moles determined by the DPNH method and 4×10^{-3} moles based on the production of ammonia. The enzyme activity seems to depend on manganese and magnesium, since deficiencies of either metal in the felts caused a marked decrease in enzyme activity. The enzymes could be reconstituted *in vivo* in the felts by returning the deficient metal to the culture medium. Experiments are in progress to determine whether these metals are essential constituents of the purified enzyme. The enzyme has a phosphate requirement which is completely replaced by arsenate, but there is no evidence for a phosphorylating mechanism.

Effects of Zinc and Iron Deficiencies on some Enzymes in Neurospora.

The effects of various intensities of iron and zinc deficiency have been determined on a range of enzymes. Iron deficiency reduced catalase, peroxidase, cytochrome c reductase and its oxidase (in that order) and diphosphopyridine

nucleotidase (DPN'ase), whereas zinc deficiency reduced glutamic dehydrogenase. TPNH and DPNH diaphorases depleted in zinc or iron deficient felts were reconstituted within 24 hr. of returning the deficient metal *in vivo* to the felts. Responses of other enzymes to a shortage of these metals varied greatly, depending on the degree of the deficiency.

Hydrogenase in Nitrogen fixing Bacteria.

Hydrogenase prepared from *Clostridium pasteurianum* (W) was found to be very unstable not only in air but even under hydrogen. The addition of sodium dithionite was, however, found to stabilize the enzyme. The evidence to date shows that this enzyme is markedly influenced by an iron deficiency but molybdenum deficiency is without effect. Both metals, however, are required for an active fixation of atmospheric nitrogen.

In *Azotobacter vinelandii* (0 strain) hydrogenase enzyme is usually associated with cell particles and only about 5% of the total activity of the enzyme is extracted in soluble form. The following extraction method was found to release 50-60% of the total amount: the bacteria collected in a Sharples centrifuge were suspended in 0.8 M tris-(hydroxy-methyl)-amino methane buffer and were crushed in a Hughes press at -30°C . The hydrogenase obtained in this way is more stable than the one prepared from *Clostridium pasteurianum* and stores well under hydrogen.

Valency States of Metals in relation to Cytochrome c.

The effects of Fe^{2+} , Mo^{5+} , Mo^{1+} , Cu^{1+} , and W^{3+} , on the chemical reduction of cytochrome c have been studied in various buffered solutions.

Biochemistry.

The Effect of Nutrient Status on Metalloporphyrin Compounds in Leaves.

Of the two main classes of metalloporphyrin compounds occurring universally in green leaves the magnesium derivatives (chlorophylls) have been widely studied in relation to the chlorotic symptoms common to many nutritional disorders. On the other hand, the iron porphyrin (haem) compounds, which also occur in relatively high concentrations in leaves, have received little attention in nutritional studies.

Work has therefore been started to determine the effects of micro-nutrient deficiencies on the concentration of the two classes of metalloporphyrins in the leaf. Measurements of total haem and chlorophyll have been made on a variety of plant species grown in sand culture. Normal plants were compared with plants in which chlorotic symptoms had been produced by simple iron deficiency and by other treatments.

Preliminary results show that in all species studied the relative concentrations of haem and chlorophyll in the leaf are remarkably constant. When chlorosis is produced, and independently of the cause of the chlorosis, the ratio of the concentrations chlorophyll/haem in the chlorotic leaves does not change greatly although the absolute concentrations may vary by as much as tenfold.

When iron is limiting in simple iron deficiency-chlorosis both haem and chlorophyll concentrations are related to the level of total iron in the leaf.

This is illustrated by results with maize leaves :

			Concentration (μ mols/g. fresh wt.)	
			Normal leaves	Fe-deficient leaves
Total Fe	..	..	2.8×10^{-1}	0.7×10^{-1}
Haem Fe	..	..	2.8×10^{-2}	0.4×10^{-2}
Chlorophyll	..	..	1.55	0.2

Measurements on leaves in which iron deficiency symptoms were produced by excess CaCO_3 in the rooting medium showed a similar pattern. On the other hand, in chlorotic leaves from magnesium deficient plants, or from plants grown without molybdenum with nitrate as nitrogen source, haem and chlorophyll were diminished in proportion but independently of the total iron content of the leaf.

Isolated Chloroplasts.

In the measurements above the concentration of chlorophyll, located entirely in chloroplasts, was related to total cell haem. Further measurements on isolated chloroplasts showed that about 60% of the total iron and 60% of the leaf haem were also located in the chloroplasts. There the haem occurs principally as the haem protein compounds, cytochromes b_6 and f .

Attempts made to obtain cytochrome b_6 in soluble form were not successful. A method was, however, devised whereby cytochrome f could be extracted in high yield from cell-free preparations of chloroplasts, from acetone powders of leaves and from whole leaves. Hitherto it has been possible to measure this cytochrome component only in insoluble form in acetone powders, and to extract it from intact leaves of few plant species.

Organic Chemistry.

In 1954 a tentative identification of *p*-coumaryl quinic acid was made by means of paper chromatography and colour tests. Several hundred milligrams of pure material have now been isolated. Immature fruitlets of the cider apple Yarlington Mill are the best source so far found ; but even in this variety the amount of *p*-coumaryl quinic acid is much less than that of chlorogenic acid. The latter compound, together with other *o*-dihydric phenols, was removed from the extracts by lead precipitation, and the mono phenols fractionated in a Craig counter-current apparatus. Two isomers of *p*-coumaryl quinic acid were found : that present in larger amount corresponds chromatographically to chlorogenic acid, the other to neo-chlorogenic acid. It is the former isomer, corresponding to chlorogenic acid, which has been isolated, giving a good analysis and equivalent. Smaller amounts of the other isomer await further purification.

Regeneration of the precipitated lead salt afforded a quantity of chlorogenic acid at least three times as great as the yield of *p*-coumaryl quinic acid. Thus quantitatively this compound is much less important than chlorogenic acid in the apple fruit, for the variety Yarlington Mill was chosen, after a wide chromatographic survey, as containing the highest proportion of *p*-coumaryl quinic acid relative to chlorogenic acid.

A detailed investigation has been made of the phenolic fraction of the leaf of Yarlington Mill, of which phloridzin was already known to be the main

component. Foremost among the other components was a group of flavonol glycosides deriving from quercetin and, to a much lesser extent, kaempferol. The most important are the glucoside, galactoside and rhamnoside of quercetin : smaller amounts of quercetin rhamnoglucoside, arabinoside and xyloside were also present. Possibly because of the smaller quantities involved, identification of all the kaempferol glycosides is less certain. The rhamnoglucoside is certainly, and the rhamnoside, arabinoside and xyloside are probably present; no positive identification of the glucoside or galactoside has been made. Small amounts of chlorogenic acid and the isomeric *p*-coumaryl quinic acids were found.

Work continues on other phenolics deriving from apple and pear trees.

Inorganic Chemistry.

Research on metallic valency states was directed towards special aspects of the chemistry of gold, titanium, and tungsten.

Gold. Previous work on the 8-hydroxyquinoline complexes of copper prompted an investigation into the existence of similar compounds with gold. An oxine complex of trivalent gold, which approximated to the formula $\text{AuCl}_2\text{C}_9\text{H}_6\text{ON}$ was prepared by the action of oxine upon "monopyridine gold chloride" and chlorauric acid under regulated conditions. The compound, which did not fluoresce in U.V. light, possessed peaks of absorption at $400\text{ m}\mu$ and $580\text{ m}\mu$. No evidence for the existence of an aurous-oxine complex was forthcoming.

Titanium. A partial separation of tri- and tetra-valent titanium was obtained upon paper chromatograms; although 136 different mixtures were tried as eluants, restrictions were imposed upon the method by the strong tendency of trivalent titanium to revert to the tetravalent state in a relatively non-polar medium. A complex of trivalent titanium with oxine, which was too unstable to be analysed accurately, was prepared by treating titanous chloride with oxine in an inert atmosphere. The compound appeared to be non-fluorescent in U.V. light and possessed an absorption peak at $660\text{ m}\mu$.

Tungsten. Under controlled conditions hexavalent tungsten in the form of WCl_6 or WOCl_4 was reduced quantitatively to the tetravalent state by zinc dust and hydrochloric acid. Zinc ions were removed from the solution by cellulose column chromatography, but a quicker method was later developed in which the tetravalent tungsten was precipitated by acetone, the zinc remaining in solution. The valency of the reduced tungsten was found by relating the concentration of W (determined gravimetrically as WO_3) in the solution to titre values with standard KMnO_4 solution.

Tungsten pentabromide was also reduced to a lower valence state (presumably IV) by zinc and ethanolic hydrogen bromide, but the reduced solution appeared to be more readily oxidised than the chloride solutions.

Soil Biology.

Using a tropical soil of sandy texture and lacking in structure, it has been shown that incubation at 25°C with supplements of sucrose, glucose or fructose leads to the aggregation of the soil into crumb-like particles.

The percentage of the soil aggregated into crumbs rises to a peak during the incubation. The rapidity with which the peak is reached and the percentage of soil aggregated are affected by the nature of the carbohydrate and the mineral nutrient content of the soil. With cellulose as carbohydrate, aggregation is very slight even in 12 months, unless a mineral supplement is included along with cellulose, when aggregation is comparable to that occurring with a glucose supplement. After the peak has been reached there is a gradual fall in the percentage of soil in aggregates as the period of incubation is extended. This is attributed to the microbiological destruction of organic binding materials.

During the formation of aggregates 60% or more of added potassium or magnesium is rendered unextractable by water ; as the percentage of aggregated soil decreases on continued incubation these immobilized nutrients are released. The behaviour of other nutrients has not been studied in detail, but molybdenum has been found to be immobilized during crumb formation.

Sterilized soil does not form aggregates under any of the conditions tested. Five fungal micro-organisms present in the soil have been isolated in pure culture.

Field work in connection with fertilizer investigations in The Gambia has again been planned and carried out.

ROOTSTOCKS AND STEMBUILDERS FOR CIDER TREES : NURSERY TRIAL.

By A. I. CAMPBELL.

Introduction.

Although great advances have been made in the use of clonal rootstocks for culinary and dessert apples during the last half century, it is still usual to raise cider trees on crab seedlings. None of a number of rootstock trials made with the more important cider varieties during the past 30 years has shown any of the vigorous clonal rootstocks to have marked advantage over well selected seedlings.

Malling XVI has been the most satisfactory of the various types tried : although the trees have been smaller than those on seedling rootstocks, they have cropped heavily and have had good anchorage. M.I has cropped quickly, but yields have soon been surpassed by those of trees on more vigorous rootstocks ; trees on M.XII have not been well anchored and those on M.XIII have produced poor crops.

While little information is yet available on the performance of Crab C in the cider orchard, it has shown promise in recent trials and all trees examined appear well anchored.

Further tests of M.XVI and Crab C against crab seedlings have been made in a nursery trial laid down in 1954-55. This trial also included M.XXV, M.3430 and *Malus toringoides*. Since it has been found that Crab C can form a satisfactory standard without the use of a stembuilder (1) each rootstock was tested by "running-up" with and without an intermediate stem of Bulmer's Norman.

Experimental.

Treatments.

(a) *Rootstocks.*

- (1) M.XVI : included as control.
- (2) Crab C.
- (3) M.XXV (Northern Spy x M.II) : introduced and distributed by East Malling Research Station (2). It has compared favourably with M.XVI in dessert apple trials, being equally vigorous and promoting earlier bearing even under conditions of very light pruning.
- (4) M.3430 (M.XII x M.IX) : one of the M.IX crosses raised at East Malling but not yet distributed. Preliminary trials have suggested that this will be a very vigorous stock (3) and will promote early fruit bud formation.
- (5) *Malus toringoides* : a vigorous apomictic seedling rootstock of greater uniformity than crab or cider seedlings, also promising greater precocity (4).
- (6) Seedling Crab (2 yr.) : the standard rootstock used for cider tree production ; very vigorous, well anchored, but slow to come into cropping.
- (7) Seedling Crab (1 yr.) : introduced to compare the performance of trees on seedlings of different ages.

(b) *Stembuilders.*

- (1) Budded at 4" from ground level during 1955 with Bulmer's Norman, the cider variety most commonly used for this purpose, cut down to the bud in the spring of 1956 and then run up for two years.
- (2) Cut down in the spring of 1956 and then run up, without a stembuilder variety, for two years.

Layout.

The layout consisted of 15 main plots, arranged as 5 blocks (replicates) for head working at 6' 6" with the three cider varieties Tremlett's Bitter, Yarlington Mill and Stoke Red, selected because of their widely differing growth habit. Each main plot consisted of 14 sub-plots, each of which contained four trees of the 14 stock-stem combinations.

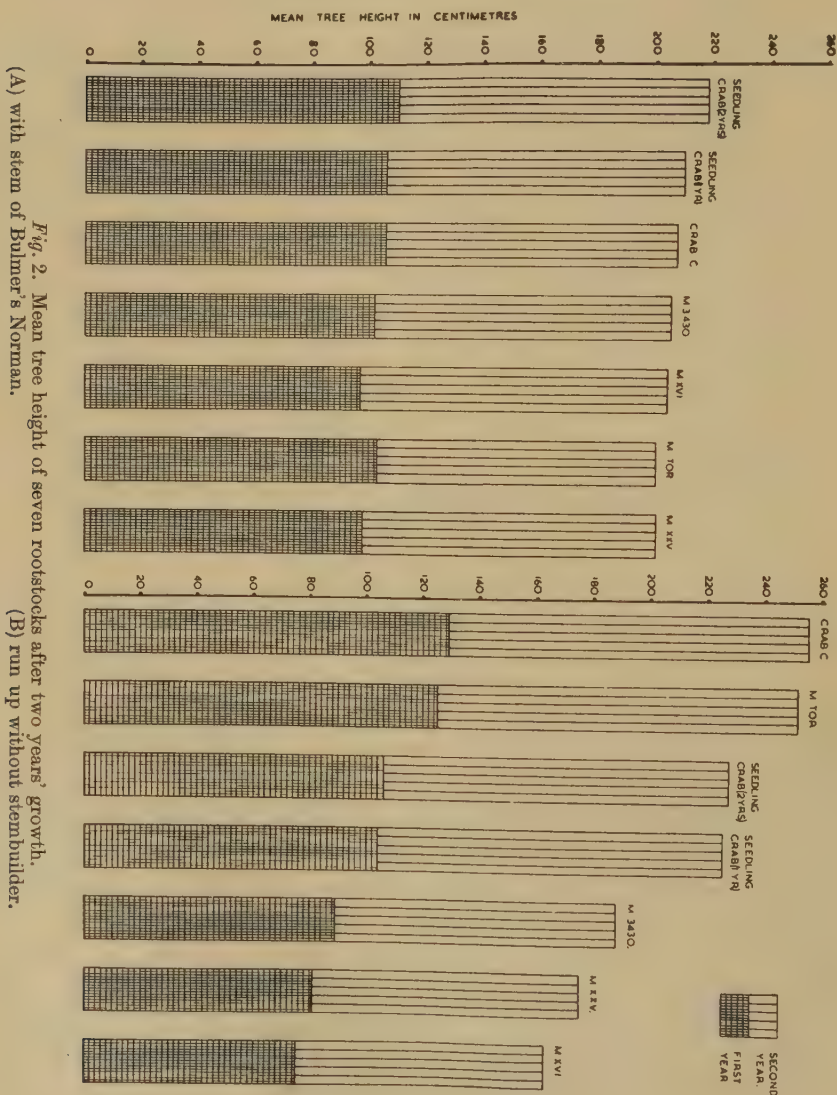
Records.

The diameter of the rootstocks was measured at 3" from ground level, immediately after planting and again at the end of the maiden year. The height of the young trees and the diameter at 10" above ground level were measured at the end of the maiden and second year.

During the first and second season all the thick feathers and laterals arising from the main stem were pruned back at regular intervals to 4 or 5 inches; those greater than 6 mm. in diameter were removed at the point of origin.

Results.

Average specimens of each of the seven rootstocks after running-up for two years are shown in Fig. 1, while mean heights are recorded in Fig. 2. It will be seen that on their own stems M.XVI, M.XXV and M.3430 failed to reach a height of 6' 6" (200 cm.) in two years. While the other four stocks reached the necessary height, only Crab C produced a satisfactory type of stem.



M. toringoides and the seedling crabs were too thin to graft and also produced too many feathers.

The Bulmer's Norman-Crab C stembuilder-rootstock combination shown in Plate I is typical of the very satisfactory growth given by this stembuilder on all rootstocks: it will be seen from Fig. 2 that there was a difference of only 17 cm. between trees on the strongest rootstock (seedling crab, 2 yr.) and those on the weakest (M.XXV). Besides exerting a levelling effect the stembuilder seems also to have interacted differently with the various rootstocks, since the heights of the combinations are not in the same order as those of the run-up stems.

TABLE I.
ROOTSTOCK AND STEMBUILDER DIAMETER.

Rootstocks	Mean Rootstock Diameter at 3"			Mean Stem Diameter at 10"			
	At planting	1 year after budding with Bulmer's Norman	1 year unbudded	1 year after budding with Bulmer's Norman	2 years after budding with Bulmer's Norman	1 year Run-up	2 years Run-up
M.XVI	1.0	1.7	1.6	1.2	2.0	1.1	1.6
M.XXV	1.2	1.7	1.6	1.2	2.0	1.0	1.6
M.3430	1.0	1.7	1.5	1.4	2.2	1.2	1.9
Crab C	1.2	1.9	1.8	1.3	2.0	1.2	2.0
<i>M. toringoides</i>	0.9	1.7	1.6	1.1	1.8	1.0	1.7
Seedling Crab (1 year)	1.1	1.7	1.7	1.3	2.1	1.0	1.7
Seedling Crab (2 year)	1.1	1.8	1.8	1.3	2.1	1.1	1.7

Whilst its effect on stem diameter was not as striking as its effect on height, it will be seen from Table 1 that, except in combination with Crab C, Bulmer's Norman had after 2 years given stouter stems than all the run-up stocks; the differences for all varieties other than Crab C were significant at the 0.1% level. In the stembuilder-rootstock combinations the diameter of M.3430 was significantly greater (1% level) than crab seedlings; one- and two-year crab seedlings were not significantly different from each other but both were greater (5% level) than M.XVI, M.XXV and *M. toringoides*.

Analysis showed that the run-up seedlings of *M. toringoides* (coeff. of variation 8%) were more homogeneous in girth than the one- and two-year crab seedlings (coeff. of variation 14% and 12%). When worked with Bulmer's Norman, *M. toringoides* had a coefficient of variation of 8%, compared with coefficients of 11% and 10% for Crab C and M.XVI respectively.

The similarity in the performance of one- and two-year-old crab seedlings suggests that there is no advantage in using older seedlings provided the one-year-old rootstocks are large enough to be budded.

Summary.

A nursery trial is described in which seven types of seedling and clonal rootstocks were tested for their suitability for building standard cider trees. Each type was run-up to form its own stem and was also budded with the stembuilder Bulmer's Norman.

Only Crab C was found to be suitable for running-up. All types, however, gave a satisfactory tree when worked with Bulmer's Norman which by its dominating influence greatly reduced the effect of the rootstock.

The Crab C trees and the seven Bulmer's Norman-rootstock combinations have been worked with the cider varieties Tremlett's Bitter, Yarlington Mill and Stoke Red and are being used in a field trial to compare vigour, cropping and general performance.

Acknowledgments.

Thanks are due to Mr. J. S. Coles for assistance in the collection of records, to Mr. G. M. Clarke for carrying out the statistical analysis and to Mr. D. E. Aliband for the photograph.

REFERENCES.

- (1) CAMPBELL, A. I. (1956). Stembuilders for cider trees : nursery trials. *Ann. Rep. Long Ashton Res. Sta. for 1955*, 46-50.
- (2) PRESTON, A. P. (1953). Five new apple rootstocks. *Ann. Rep. East Malling Res. Sta. for 1952*, 169-170.
- (3) PRESTON, A. P. (1954). Apple rootstock studies : the M.IX crosses. *Ann. Rep. East Malling Res. Sta. for 1953*, 89-94.
- (4) LUCKWILL, L. C. and CAMPBELL, A. I. (1954). The use of apomictic seedling rootstocks for apples : progress report. *Ann. Rep. Long Ashton Res. Sta. for 1953*, 47-52.

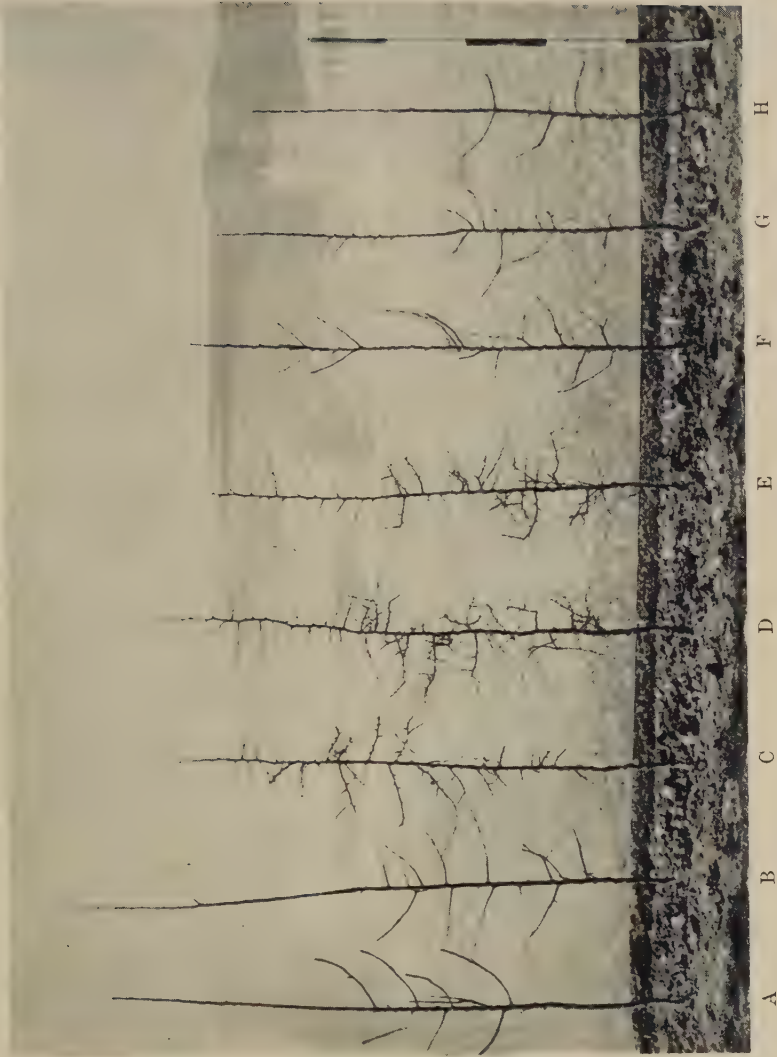
MALE STERILITY IN BRISTOL CROSS PEAR.

By D. WILSON.

Introduction.

The pear variety Bristol Cross, which was bred at Long Ashton from a cross of Williams and Conference and was first distributed in 1933, has proved a regular and prolific cropper, and, since it fills a useful place in the succession of commercial pears, is now being planted on an increasing scale in this country. Its popularity has led to enquiries regarding its self-compatibility, and, in particular, its value as a pollinator for Conference and other commercial varieties. The following investigation was undertaken to obtain information on these points.

A series of pollination tests which it was planned to carry out with this variety in 1956 was abandoned when it was found, by microscopic examination, that over 90% of the grains in the pollen samples collected from Bristol Cross trees at Long Ashton were abortive. In 1957 flowers were collected from Bristol Cross trees in different localities and the development of the pollen grains was studied from an early stage in order to determine the nature and extent of pollen abortion in this variety.



A = Bulmer's Norman on Crab C.

B = Crab C.

C = *Malus toringoides*.

D = Seedling Crab (2 yr.).

E = Seedling Crab (1 yr.).

F = M.3430.

G = M.XXV.

H = M.XVI.

Fig. 1. Rootstocks and stembuilders run up for top-working cider trees.

Experimental.

For the early stages (from first metaphase to tetrad formation) flower buds were fixed in acetic alcohol containing iron acetate and stained in aceto-carmin by the technique of Thomas (1). Later stages were examined after mounting in aceto-carmin glycerol jelly as described by Marks (2). Mature pollen grains from trees growing in different parts of the country were also examined by the above method.

Pollen germination was tested by using the hanging drop technique with various combinations of sucrose and boron in the culture media.

Finally, by controlled pollinations, the effectiveness of Bristol Cross pollen in setting fruit on Bristol Cross was compared with that of Conference and Laxton's Superb. A small number of unpollinated units were left as controls. For these tests Bristol Cross flowers (reduced to 3 per spur) were high-emasculated at balloon stage, protected by Pergamine bags, and pollinated 1-2 days later, when the stigmas were receptive, with pollen collected a day earlier and dried overnight at room temperature. Fruit-set records were taken at monthly intervals and after the fruit was harvested; the seed content of each fruit was checked and noted.

Results.

The cytological examination of early stages of pollen grain development revealed that Bristol Cross is a diploid, as would be expected of a seedling of diploid parents (Williams and Conference). At first metaphase the chromosomes associated as 17 bivalents as in a normal diploid meiosis, and there was no evidence of irregularities (chromosome bridges, lagging chromosomes, etc.) in later stages of meiosis. For the first two weeks after the tetrads had divided, all the resultant grains were uniform in size and shape. However, in the third week, oval shaped grains with longitudinal sutures appeared amongst the normal

TABLE I.
ABORTED POLLEN IN BRISTOL CROSS.

Source of Pollen	Aborted grains	Normal grains	% Aborted grains
Long Ashton 15/19 ..	210	12	94.6
Long Ashton 15/18 ..	320	14	95.8
Long Ashton 15/21 ..	443	20	95.7
Long Ashton 15/20 ..	511	35	93.6
Long Ashton 15/22 ..	352	35	91.0
Long Ashton 15/17 ..	462	54	89.5
Long Ashton 5/8 ..	194	19	91.1
Long Ashton 5/9 ..	966	64	93.8
Long Ashton (G.C.) ..	369	31	92.3
Failand	398	21	95.0
Epsom	927	85	91.6
Wisley	336	20	94.4
Liss	507	35	93.5
Chelmsford 1	285	27	91.4
Chelmsford 2	222	22	91.0
Chelmsford 3	664	66	91.0
Total	7166	560	92.8

Each figure is derived from the total of 3 traverses from each of two slides.

rounded grains and their proportion increased rapidly during the following weeks until, at maturity, over 90% of the grains were of this type.

When mature pollen from various sources was examined there was a high proportion of aborted grains in every sample and, as is shown in Table I, the percentage varied from 89.5 to 95.8. Thus it was apparent that only about 1 in every 10 Bristol Cross pollen grains was functional.

A series of germination tests using varying concentrations of sucrose and boron confirmed that the small oval grains were non-functional. Of the normal grains the highest germination rate (36 germinated in 141 examined) occurred

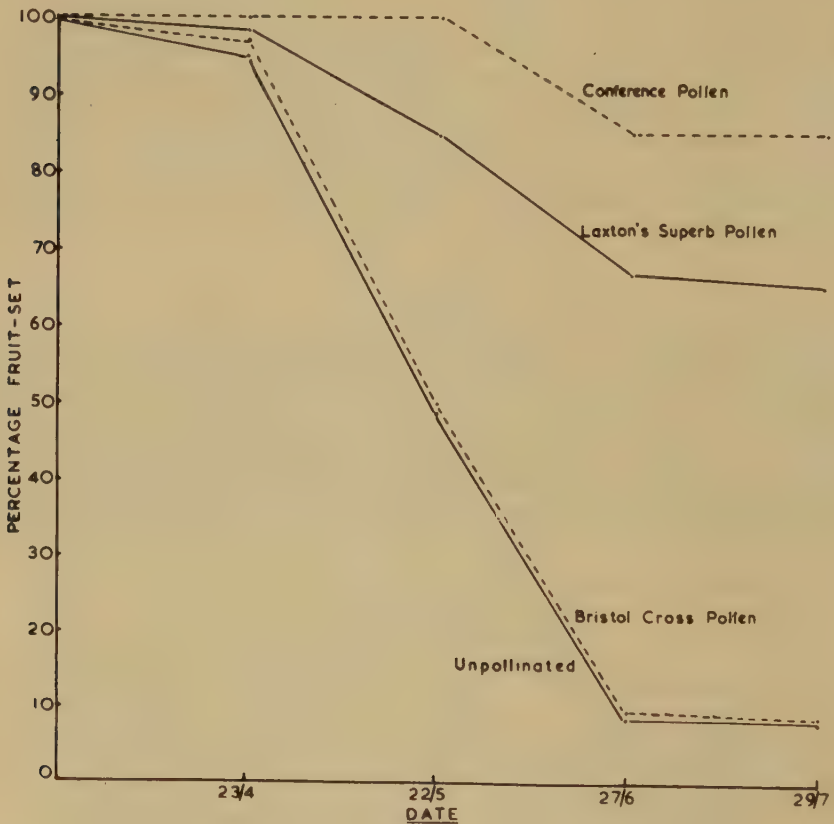


Fig. 1.—Fruit set of Bristol Cross after controlled pollination.

TABLE II.
SEED NUMBER IN BRISTOL CROSS PEARS.

Pollinator	Seed Content	
	Range	Mean
Conference	0-7	4.6
Laxton Superb	0-10	2.8
Open pollinated	1-7	3.1
Bristol Cross	0	0
Unpollinated	0	0

in a culture medium containing 10% sucrose and 50 p.p.m. boron at a temperature of 24°C.

Figure 1 summarizes the results of the controlled pollination experiments and Table II lists the seed content of the fruits obtained from the different pollinations. From Figure 1 it can be noted that, although in the early stages fruit-set in all treatments was comparable, the final fruit-set figures where Bristol Cross pollen was used are almost equivalent to the unpollinated controls, and that both Laxton's Superb and Conference pollen produced a vastly superior fruit set. Table II shows that no seeds were present in fruits obtained from unpollinated flowers or from flowers pollinated with Bristol Cross pollen. Conference pollen produced the highest average seed content, open-pollinated fruits the second highest and Laxton Superb the third highest. A small percentage of the fruits having no seed had the typical parthenocarpic sausage-shape but the majority were quite normal in shape.

Discussion.

Whilst formal experiments, in which Bristol Cross pollen would be tested on the varieties for which it is a proposed pollinator, have not been made, it is apparent from the above results that Bristol Cross cannot be regarded as a potential pollinator for any pear variety. The consistently high percentage of aborted pollen makes it extremely unsuitable for such purposes.

Almost complete male sterility is unusual in a diploid pear, the only comparable example being Marguerite Marillat (3). As yet it is not known whether the manifestations of male sterility are the same in both varieties.

The cause of male sterility in Bristol Cross can, at the present time, be deduced only by indirect evidence and by eliminating certain possible causes. As the high rate of pollen abortion has occurred in two years it is not unreasonable to eliminate seasonal and climatic factors as causative agents. The fact that pollen from several sources was similar in having a high rate of pollen abortion suggests that it is not due to cultural conditions. Further, as Bristol Cross shows no observable irregularities during meiosis it seems unlikely that the cause of male sterility is in the cytological mechanism of pollen grain formation. Having thus eliminated most of the possible causes it seems probable that the cause of pollen abortion is genetic in nature. This hypothesis is further supported by the following facts: first, the percentage of aborted pollen is so closely similar in all the samples examined that it seems probable that there is a constant segregation ratio. Secondly, from unpublished data of Spinks, the breeder of Bristol Cross, it is apparent that at least one of the seedlings from the same family was suspect for male sterility in that it failed to set fruit when used as pollen parent. Finally, in one of a family of seedlings of Bristol Cross x Comice parentage there was also a high percentage (56.5) of aborted pollen.

If, as seems probable, the male sterility of Bristol Cross is genetic in origin, the lethal genes are most likely to have come from Williams since a gene for pollen lethality cannot be inherited through a male parent. On checking a small sample of Williams pollen it was apparent that there were some aborted grains present but the percentage was quite low (7%). To obtain concise evidence on the nature of the segregation of the lethal gene or genes further precise pollen analyses will have to be made on Williams, Bristol Cross and the latter's sister seedlings and progeny.

Summary.

A study of pollen development, pollen germination and controlled pollinations with Bristol Cross pear has shown that this variety may, for all practical purposes, be regarded as male sterile, since it produces only 5 to 10% of viable pollen grains. Although Bristol Cross is itself capable of setting heavy crops when cross pollinated it should not be regarded as a pollinator for Conference or any other pear variety. The reasons for the high percentage of non-functional pollen grains are thought to be genetic, but further experiments will have to be undertaken to confirm this hypothesis.

Acknowledgments.

Thanks are due to the fruit growers who provided Bristol Cross flowers, to Mr. M. W. Case who collected much of the material and to Dr. L. C. Luckwill for his advice and guidance.

REFERENCES.

- (1) THOMAS, P. T. (1940). *Stain Tech.* **15**, 167-72.
- (2) MARKS, G. E. (1954). *Stain Tech.* **29**, 277.
- (3) CRANE, M. B. and LAWRENCE, W. J. C. (1947). *The Genetics of Garden Plants* (3rd edn.), Macmillan, London.

VIRUS DISEASES OF FRUIT TREES: VI. GRAFT TRANSMISSION OF CHAT FRUIT.

By L. C. LUCKWILL.

Introduction.

In a previous paper of this series (1) a description was given of the disease known as "chat fruit", as it affects the apple variety Lord Lambourne, and some evidence was adduced to show that the condition was transmissible from infected to healthy trees by grafting and was therefore caused by a virus.

The evidence for graft transmissibility was derived from experiments in a commercial orchard in which chat fruited trees had been headworked with scions from healthy trees. The following year these scions carried fruit that was definitely chatted, but unfortunately the orchard was then grubbed, and no further observations could be made. Apart from this fact, it is realized that the evidence from headworking is not an infallible proof of graft transmissibility, since it is conceivable that the small size of the fruits carried by these trees might have been due to other causes, e.g. nutritional deficiency, poor graft union, waterlogging etc. For this reason a more critical experiment was planned, in which an attempt was made to transmit chat fruit from diseased to healthy trees by means of buds and bark grafts. The details of this experiment are given below.

Experimental.

The trees used for this experiment were part of a block of Lord Lambourne grown as dwarf pyramids on M.II rootstocks at Long Ashton. The trees were planted in 1952/53 and by 1956, when the experiment was started, had already

carried several crops of apples which were in every way normal and typical of the variety. No rubbery wood or mosaic had been seen on the trees chosen for the experiment.

The infection material came from two standard trees of Lord Lambourne growing in an orchard in Worcestershire which had consistently produced crops of small green fruits typical of chat fruit. These two trees are referred to as sources A and B. In August 1956 bark from these trees was used to inoculate 20 of the healthy pyramid trees at Long Ashton, 4 to 6 small bark chip grafts being placed on the main limbs of each tree. A further 10 pyramid trees were infected with a similar number of buds, inserted by the usual T-budding method. An adjacent block of 17 trees was left un-inoculated as controls.

Results.

In 1957, 13 months after inoculation, all the experimental trees carried a heavy crop and inspection showed that some of the inoculated trees were severely chatted. Others carried fruits that appeared only slightly sub-normal in size and colour and were designated as "possibly chatted". At harvest the fruits from both inoculated and control trees were weighed and graded, with the results shown in Table I and Fig. 1.

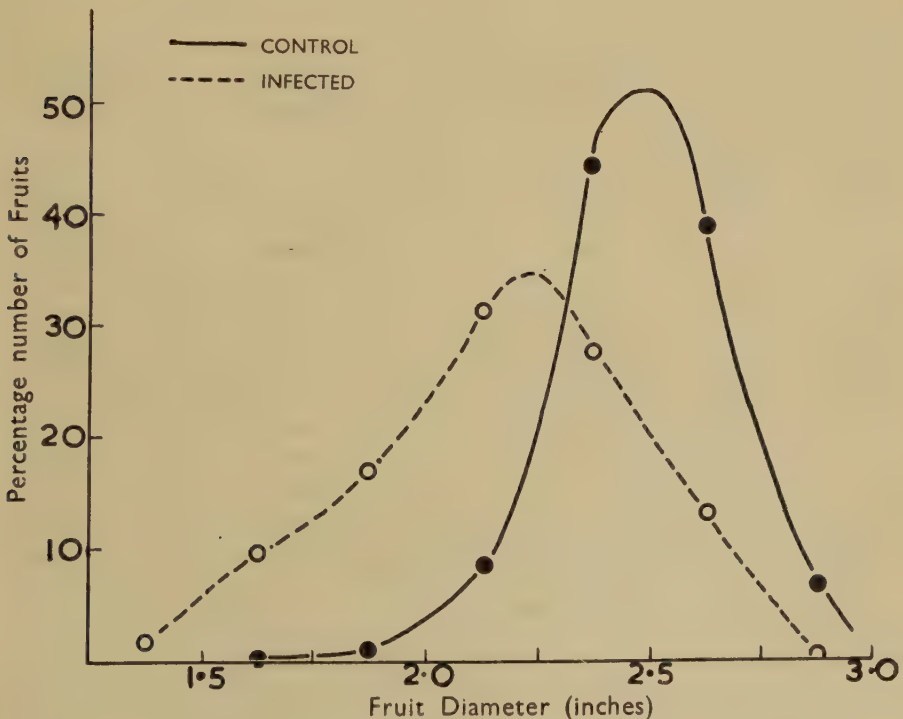


Fig. 1.—Effect of chat fruit virus on size of Lord Lambourne apples in the year following infection. The curves show the fruit size distribution for 17 control trees and 20 trees infected from Source B (see text).

TABLE I.

GRAFT TRANSMISSION OF CHAT FRUIT IN LORD LAMBOURNE.
Trees inoculated August, 1956; records taken September, 1957.

	Controls	Inoculated		
		A	B	B
Source of inoculum	—	Bark	Bark	Buds
Method of inoculation	—	chips	chips	
Number of trees	17	10*	10	10
No. of trees definitely chatted ..	0	1	4	8
No. of trees possibly chatted ..	0	2	1	2
Mean crop per tree (lb.)	5.36	7.75	6.45	5.14
Mean no. fruits per tree	20	32	30	28
Mean weight per fruit (lb.) ..	0.268	0.249	0.215	0.183
Per cent. fruits under 2½" diam. ..	1	10	20	35
Per cent. fruits 2½" or over ..	99	90	80	65

* All trees inoculated from source A developed symptoms of apple mosaic in 1957.

Discussion.

The results of this experiment leave no doubt that the chat fruit condition of Lord Lambourne is a graft-transmissible disease caused by a virus. A surprising feature of the experiment is the fact that such definite and well marked effects on fruit size were obtained in the first year after inoculation (see Fig. 1), since viruses affecting only fruit characters are often slow to manifest themselves.

There were well marked differences in the results obtained by the two different methods of inoculation and between the two sources of inoculum, buds proving superior to bark chip grafts and source B giving a higher percentage of infected trees than source A. Although, in the 10 trees inoculated by bark chips from source A, only one was recorded by visual inspection as being definitely chatted, the virus seems to have had an effect on the mean fruit weight and on the percentage of fruits less than 2½" in diameter. (Table I). These trees will be kept under observation and it is possible that in future years the number of chatted trees will increase. The apparently low transmission of chat fruit in this group of trees cannot be attributed to a poor "take" of grafts since all trees developed severe symptoms of apple mosaic in 1957, apparently transmitted from the parent tree (source A), although no symptoms of mosaic were noticed on this tree in August 1956, when the grafting material was collected. One possible explanation of this is that mosaic-infested leaves had been shed from the tree by this time so that the infection was not noticed. The greater success of the bark chip inoculations from source B, using similar methods and materials, may possibly indicate the existence of strains of the chat fruit virus that vary in their virulence, though further work would be needed to establish this with certainty. The high percentage transmission achieved by the use of bud inoculation suggests that this method, used on small fruiting trees of Lord Lambourne, might form the basis of a relatively quick method of indexing rootstocks and scion material for latent chat fruit virus.

Acknowledgments.

I am indebted to Mr. A. I. Campbell, Mr. J. S. Coles, Mr. P. S. Weaver and Mr. N. T. Weatheritt for help with this experiment.

REFERENCE.

- (1) LUCKWILL, L. C. and CROWDY, S. H. (1950). Virus diseases of fruit trees : II. Observations on rubbery wood, chat fruit and mosaic in apples : progress report. *Ann. Rep. Long Ashton Res. Sta. for 1949*, 68-79.

THE PROPAGATION OF GOOSEBERRIES : VI. THE INFLUENCE OF SOURCE ON THE ROOTING OF HARDWOOD CUTTINGS.

By BARBARA A. RAKE.

Introduction.

Although not recorded for gooseberries, in many species the condition of the source plant is known to affect the rooting of cuttings taken from it. Myrobalan B cuttings, for instance, are known to give a higher percentage of rooting when taken from a hedge than when taken from rooted cuttings in nursery rows (1). The experiment reported here tested the effect of three different sources of cuttings.

Experimental.

Cuttings were taken from the following sources :—

- (1) Stool bushes grown exclusively for propagation work and cut back to ground level annually.
- (2) Two-year old bushes lined out in nursery rows.
- (3) Eight-year old fruiting bushes.

Using the varieties Leveller, Keepsake and Careless, each treatment was replicated four times in randomised blocks, giving 36 plots. The cuttings were prepared 10" long, with buds removed except for four at the top, and were planted in mid-September immediately after preparation. In order to make them comparable with other treatments the bases of the stool shoots were removed during preparation though, as shown in subsequent experiments, this slightly etiolated basal portion contributes greatly to the superior rooting performance of stool cuttings. The cuttings were planted 6" apart in rows 3' apart ; each plot consisted of 12 cuttings, 10 of which were recorded. Records were made at the end of the following season of percentage "take", and vigour was scored in categories 1-10.

Results.

Table I gives the results for the three varieties taken from three different sources. Over all varieties, cuttings from stools and fruiting bushes gave a take significantly higher (at the 5% level) than those from young bushes. Careless showed a better "expected" take (2) from young bushes, while the performance of cuttings of this variety from stools was not so good as the "expected" value.

TABLE I.
ROOTING AND VIGOUR OF CUTTINGS FROM DIFFERENT SOURCES.

	Leveller		Keepsake		Careless	
	Rooting	Vigour	Rooting	Vigour	Rooting	Vigour
Stools	85	7.0	92	9.0	85	8.2
Young bushes ..	42	5.0	62	6.2	95	9.0
Fruiting bushes ..	72	5.7	82	6.7	95	8.2

Rooting=percentage. Vigour=0—10.

Summary.

Experiments are described which test the effects of different types of source bush on rooting and subsequent vigour of cuttings.

With the varieties Leveller and Keepsake, cuttings from stools and fruiting bushes gave a significantly higher take than those from young bushes.

REFERENCES.

- (1) SINHA, A. C. and VYVYAN, M.C. (1942) *J. Pomol.* **20**, 127.
- (2) RAKE, BARBARA A. (1955) *Ann. Rep. Long Ashton Res. Sta. for 1954*, 63.

THE CLASSIFICATION OF GOOSEBERRIES: I. USEFUL CHARACTERS FOR THE CLASSIFICATION AND IDENTIFICATION OF VARIETIES.

By BARBARA A. RAKE.

It is evident from discrepancies in the naming of gooseberry varieties obtained from different sources that their nomenclature is very mixed. Existing descriptions of varieties deal mainly with the characters of the mature fruit. Although these are probably the most decisive, nurserymen are often dependent on the recognition of varieties by vegetative characters, since the fruit may not reach the necessary advanced stage. A scheme is being developed by which characters can be used for identification purposes at different times of the year.

Characters Examined During the Winter.

These are best studied over the period December-January. Although there are not many diagnostic characters at this stage, those that are useful can be examined over a considerable period of time, unlike blossom and leaf characters, which quickly change. Identification by winter characters is useful for nurserymen who normally send out bushes for sale at this stage.

Bush characters.

Growth habit is a very useful characteristic as it is not influenced greatly by environmental conditions. It is more easily determined on young bushes before pruning and weight of crop have interfered with the natural habit. Growth habit can be classified as upright, upright-spreading, spreading and pendulous (Plate II).

Bush vigour is not particularly useful, although certain varieties such as Leveller are notoriously weak growers, while others (e.g. Keepsake) grow well anywhere.

Shoot characters.

These are determined on normal one-year-old shoots (not suckers) taken from the outside of the bush, using only the middle portion for the determination of characters.

Bark colour, although a useful characteristic, is difficult to define. The patchiness of the colour, black spotting due to *Phoma suspecta* and differences between the shaded and exposed sides of the shoots make matching up with a colour chart impossible. The bark colour of one-year-old shoots is basically buff, slightly tinged with grey, brown, or yellow, and to determine this the shoot has to be looked at as a whole. When examining a large number of varieties the differences are easier to see.

Splitting of the outer layers of bark has been examined: the amount appears to depend more on the girth of the shoot than on variety; some varieties are more prone to splitting than others.

Pubescence of the shoots is a useful characteristic and, like bush habit, does not vary much with growing conditions. The density of pubescence can be ascertained with a hand lens, holding the shoot over white paper. It must not be confused with the black spots due to *Phoma suspecta* which occur on most shoots.

Bud shape (broad, average or narrow) is constant for each variety, but is difficult to determine unless a large number of varieties are examined simultaneously. (Plate III, Fig. 1).

Size, poise, hairiness and colour of buds are all too variable within each variety to be useful characteristics for identification.

Internode length is also too variable.

Spine number and size are useful but both must be determined strictly on the central portions of the shoots.

Spine poise varies too much to be useful.

Spine colour is useful, but as in the case of shoot colour it is difficult to determine, unless a large number of shoots are examined. Spine colour is grouped as light, medium, dark or very dark brown.

Spine dilation at base (broad, average or slender) is also a useful characteristic. (Plate III, Fig. 2).

Characters Examined During Blossom Time.

Blossoms.

Examination of blossom characters must be carried out daily as the blossoms open, as changes in their characters occur very fast. Blossoms on one-year-old wood are best for examination; those on older wood tend to vary, particularly with regard to hairs on the ovary.

Colour in bud. This must be examined just before the blossoms open, and may be divided into red, pink, green or green-edged-red groups.

Time of blossoming does not always occur in the same order, though varieties usually blossom within the same group (early, mid-season or late).

Colour of the sepals varies with the length of time the flower has been opened, so is not useful except where pronounced red or green coloration occurs.

Shape of the ovary (round, round-oval, oval or oblong) is a useful character but must be determined when the blossom is fully developed and opened but not fertilized.

Hairiness of the ovary is one of the most useful of the blossom characters; besides being easy to determine it can be looked at over a relatively long period. Provided only blossoms on one-year-old shoots are used this character is very constant for each variety. Hairiness of the ovary is of two types—colourless pubescence and red or colourless glandular hairs. Both types are present separately and together in varying amounts.

Size of sepals, petals and ovary are all too variable to be useful.

Length of raceme is also too variable.

Reflexion of sepals and height of anthers in relation to stigma have been found to vary more with the age of the blossom than between varieties.

Leaf colour.

Leaf colour is best examined at blossom time as it is then that differences show up more clearly. Five groups, ranging from very light green to very dark green, can be distinguished.

Characters Examined During the Summer.

Foliage.

Foliage characters are examined at the end of June when the young shoots are still growing and their bases just beginning to lignify. Only current year's growing shoots are used. Often foliage characters are distorted by virus disease which is present in varying amounts in most varieties. Shoots not showing symptoms or showing only very mild symptoms can usually be obtained by hard cutting back in winter. With some varieties (e.g. Lancashire Lad) masking of virus symptoms is not possible and definite foliage characters cannot be determined.

Measurements of length, breadth, lobe length, petiole length, and ratios between these measurements, have shown that leaf size is more variable within one variety than between the varieties examined, and cannot be used as a diagnostic character.

Poise of leaf, separately defined as poise of leaf blade itself, poise of tip and poise of margins, together with positions of lower lobes (open or various degrees of inflexion) is the most useful foliage character. (Plate III, Fig. 3).

Serrations of the margin are similar in character on all varieties but coarseness varies.

Pubescence on the upper or lower surfaces of the leaf is a recognizable characteristic; the veins on the underside are always hairy and these must be avoided when making the examination.

Thickness, colour and angle of petiole are not useful characteristics.

Hairiness of the petiole on the upper and lower sides is a fairly constant character.

Young shoots.

Pubescence can be determined more easily at this time than in the winter.

Red tinge near the tips of the shoots, absent in some varieties, present in varying degrees in others, is a very constant and useful character.

Fruit Characters.

Fruit from one-year-old wood is preferable for the determination of fruit characters; colour and hairiness, particularly, are liable to vary considerably on fruits picked from older wood or from wood in the centre of the bush.

Season of ripening. Fruits usually mature in the same order each year, though the actual season varies.

Colour of fruit is a character commonly used for classification. The groups into which colour can be divided are numerous and impossible to define with a colour chart. The most satisfactory way of colour grouping is by using known standard varieties for each colour. Transparency of fruit, ranging from complete opacity to the seeds being entirely visible, further divides the colour groupings.

Pubescence and hairiness of fruit have also been used frequently in the past as a basis for classification. If only fruit from new wood is used little variation occurs.

Shape of fruit has also been used as a basis for classification and if a fairly large sample (20 fruits) is examined this character is very useful. In addition to grouping into round, oval and oblong, the amount of taper to the stem gives further divisions. (Fig. 1).

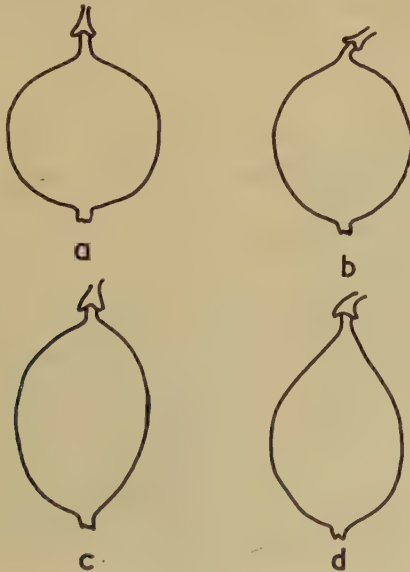


Fig. 1. Fruit Shape.

- (a) Round.
(c) Oblong.

- (b) Oval.
(d) Oblong tapering to stem.

Veining of the fruits may be useful for classifying some varieties that have either very distinct or indistinct veins; the majority of the varieties, however, come in the intermediate group.

Length, thickness and hairiness of pedicel are all useful characters provided a sufficiently large sample is examined.

Calyx (open, half-open or closed) varies too much within a variety to be useful.

Size of fruit, used comparatively between varieties grown under the same conditions, is useful, but cultural and climatic conditions naturally alter actual size.

Miscellaneous Characters.

Time of bud burst. Varieties normally fall into the same groups each year, though actual time naturally varies with the season.

Autumn leaf colour. This is quite a good character for classification, but the changes in tint are rapid and must be observed frequently.

Resistance to sulphur sprays. Although giving only two or three classification groups this is a very important commercial character to determine.

Summary.

Useful characters for describing and classifying gooseberry varieties at different stages of development throughout the year are discussed.

Acknowledgment.

Grateful thanks are due to Miss M. E. Holgate for carrying out analyses on the leaf measurements.

APPENDIX: SUMMARY OF USEFUL CHARACTERS.

Winter Characters.

Bush.

Growth habit : upright ; upright-spreading ; spreading ; pendulous.

Vigour : weak ; moderate ; vigorous ; very vigorous.

Shoots.

Bark colour : greyish buff ; brownish buff ; yellowish buff.

Splitting of epidermis : none ; slight ; moderate ; pronounced.

Pubescence : glabrous ; slightly pubescent ; pubescent ; very pubescent.

Bud.

Shape : broad ; average ; narrow.

Spine.

Number per bud : none ; one ; two ; three.

Size : long (>15 mm.) ; medium (10–15 mm.) ; short (<10 mm.).

Colour : light brown ; medium brown ; dark brown ; very dark brown.

Dilation at base : broad ; medium ; slender.

Blossom Characters.

Colour in bud : red ; pink ; green ; green edged red.

Time of blossoming : early ; mid-season ; late.

Shape of ovary : round ; round-oval ; oval ; oblong.

Hairiness of ovary : glabrous ; slightly pubescent ; pubescent ; very pubescent.

Glandular hairs on ovary : none ; few ; moderate number ; many ; very many.

Colour of hairs on ovary : red ; colourless.

PLATE II.

Growth Habit of Gooseberry Varieties.

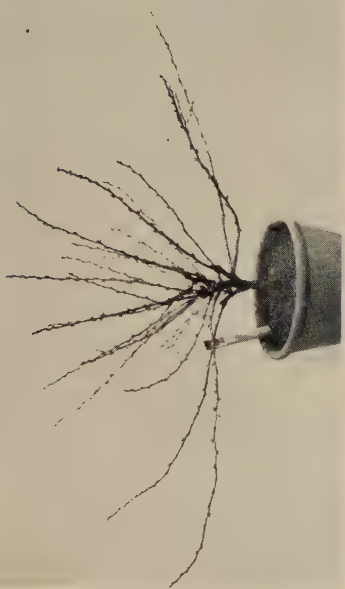


Fig. 2. Upright-spreading: BROOM GIRL.



Fig. 4. Pendulous: COUSEN'S SEEDLING.



Fig. 1. Upright: LANGLEY GAGE.



Fig. 3. Spreading: GUNNER.

PLATE III.
 Characters of Gooseberries.



Fig. 1. Bud shape.

Left. Broad : BEDFORD RED.
 Centre. Average : COUSEN'S SEEDLING.
 Right. Narrow : GOLDEN DROP.



Fig. 2. Spine Dilation.

Left. Broad : BEDFORD RED.
 Centre. Average : GOLDEN DROP.
 Right. Slender : COUSEN'S SEEDLING.



Fig. 3. Leaf Poise.

Left. Slightly cupped : BROOM GIRL.
 Centre. Flat : BEDFORD RED.
 Right. Cupped : LANGLEY GAGE.

Foliage and Shoot Characters.

Leaf colour at blossom time : very light green ; light green ; medium green ; dark green ; very dark green.

Poise of leaf : flat ; slightly cupped ; cupped ; wavy ; down-curved.

Poise of leaf tip : horizontal ; slightly down-curved ; down-curved.

Poise of leaf margins : upcurved ; horizontal ; down-curved.

Lower lobes : open ; slightly inflexed ; inflexed ; inflexed with edges meeting ; inflexed with edges overlapping.

Margin : obtuse serrate ; coarsely obtuse serrate ; very coarsely obtuse serrate.

Upper surface : matt glabrous ; glossy glabrous ; pubescent.

Lower surface : matt glabrous ; glossy glabrous ; pubescent.

Pubescence : upper side of petiole : heavy ; slight ; none.

Pubescence : underside of petiole : heavy ; slight ; none.

Young shoots.

Red tinge : none ; slight ; distinct ; very distinct.

Pubescence : glabrous ; slightly pubescent ; pubescent ; very pubescent.

Fruit Characters.

Season of ripening : early ; early-mid-season ; mid-season ; mid-season-late ; late.

Colour of fruit : dark crimson (Crown Bob) ; crimson (Lancashire Lad) ; bright crimson (Warrington) ; crimson with greenish tinge (Dan's Mistake) ; crimson with whitish tinge (Rifleman) ; dark golden yellow (Laxton's Amber) ; golden yellow (Bedford Yellow) ; greenish yellow (Leveller) ; greenish yellow with white tinge (Langley Gage) ; yellowish green (Criterion) ; pale yellowish green (Rushwick Seedling) ; olivaceous (Gunner) ; dark sea green (Green Walnut) ; sea green (Shiner) ; medium green (Bellona) ; whitish green (Keepsake) ; greenish white (Careless) ; yellowish white (Pottage) ; white (Bollin Hall).

Transparency : opaque ; slightly transparent ; transparent ; very transparent.

Pubescence : glabrous ; slightly pubescent ; pubescent ; very pubescent.

Bristles : none ; very few ; few ; moderate ; many.

Shape : round ; round-oval ; oval ; oval-oblong ; oblong.

Taper to stem : distinct ; slight ; none.

Veins : very distinct ; distinct ; not distinct.

Length of pedicel : long (>6 mm.) ; medium (3-6 mm.) ; short (<3 mm.).

Thickness of pedicel : slender ; medium ; stout.

Hairiness of pedicel : glabrous ; slightly pubescent ; pubescent ; very pubescent.

Size of fruit : large (>13 gm.) ; medium (8-13 gm.) ; small (<8 gm.).

LEAF-BUD PROPAGATION OF A VIRUS-TESTED LOGANBERRY CLONE.

By E. W. HOBBS and A. I. CAMPBELL.

Introduction.

The unsatisfactory cropping of commercial plantations of loganberries is of long standing. It was examined between 1930 and 1940 by Beakbane (1), who found that a collection of so-called loganberries, assembled at East Malling from trade sources in 1930, consisted of such a varied range of plants that the word loganberry could be considered only as a group name. Investigations in commercial plantations confirmed the mixed nature of supposed loganberry stocks and the consequent unsatisfactory cropping.

From the East Malling collection of plants it was possible in 1932 to select one which appeared to be identical with the original loganberry in vegetative and fruit characteristics ; from this a clone was raised (2). Plants from

this clone were first distributed in small number in 1939, and in 1942 plants were sent to Long Ashton to form a small nursery where, under strict conditions of pest and disease control, propagation by tip-layering was carried out until 1955. In addition a quarter-acre of plants was raised and set out at Long Ashton for fruit production, as part of a general collection of blackberries and hybrid berries. The loganberries cropped reasonably well over a period of 10 years.

In connection with a further collection of loganberries made by East Malling in 1954 and 1955, plants from the Long Ashton nursery were sent back to East Malling in 1954 for virus testing. These tests showed that plants of the Long Ashton stock were free from a virus known to cause degeneration. Freedom from this particular virus, coupled with a reasonable field cropping performance, and the fact that there would be no difficulty in recognizing in the field the difference between this and other stock at present in commercial use, prompted the decision to propagate the clone for extended distribution. By agreement with East Malling Research Station and the Nuclear Stocks Association, Long Ashton undertook the raising of a nuclear stock.

Five small plants, re-cloned and virus tested at East Malling, formed the nucleus from which propagation was undertaken. In order to increase numbers as quickly as possible the leaf-bud method of propagation, as described by Stoutemyer *et al.* (3) and by Garner and Hammond (4), was used ; the following account concerns plants raised in this way.

Experimental.

To gain experience and examine various techniques before the first batch of virus-tested cuttings was taken, a small scale trial was carried out on material already available at Long Ashton from the 1942 clone. Investigations showed that there was no advantage in reducing the leaf area of the cuttings or in cutting thick bud shields (see Fig. 1). Batches of 20 cuttings taken in mid-July 1956 and planted in electrically heated beds gave the following numbers of rooted plants :—

Leaf-bud with terminal lobe of the leaf removed and cut thin (not down to pith)	10
Leaf-bud with leaf complete and cut thin (not down to pith)	15
Leaf-bud with leaf complete, cut thick to include some pith	14

Except for the different methods of making the cuttings, the conditions of planting and treatment were the same throughout.

The results suggest that the greater the leaf area the better the rooting ; a similar impairment of rooting capacity by the reduction of leaf area was noticed later, when it was found difficult to root cuttings that had small or damaged leaves. The thickness of the leaf-bud shield did not appear to be of great importance and a small amount of pith at the base did not prevent rooting ; very thin bud shields did, however, tend to turn black and rot.

The five virus-tested loganberries were planted in a cold frame in John Innes potting compost on May 11th, 1956, and the frame lights were put on only when necessary to protect them from strong sun and frost. Growth was rapid,

and new canes were long enough to provide the first batch of leaf bud cuttings on August 9th.

The cuttings were planted in a compost prepared from equal parts of sterilized loam, peat and grit; this medium seemed perfectly satisfactory for the early stages of rooting. Each cutting was inserted individually into a 3" pot which was plunged into peat to prevent drying out; this method made it easier to move the plants as soon as they were rooted, and prevented any check during the growing season.

It was found that the first few days after taking the cuttings were critical, the most important single factor being shade. Heavy shading during bright sunshine was essential to prevent scorching, and frequent overhead damping was needed to keep the single parent leaf fresh and healthy. Cuttings were also found to root better in a propagation case inside a greenhouse than in an outside frame, even when the soil in both was electrically heated to 67°-70°F.; this was presumably due to air temperature fluctuations.

The cuttings produced a large amount of callus from the exposed cambium, and roots began to appear after 3 to 4 weeks (Fig. 2). Sometimes they arose from the callus, but usually from the base of the young shoot formed from the leaf-bud (Fig. 3). If during this initial period the parent leaf died, the cutting produced roots, but no shoot appeared until the following season and establishment was consequently delayed. On a cane with 20 leaves only 10 or 12 leaf-buds along the middle section of the cane rooted satisfactorily; most of the tip cuttings and those made from immature leaf buds died.

Batches of cuttings were taken during 1956 on August 9th, 23rd, September 6th, 26th and October 16th. The last two batches of cuttings taken in late September and October gave poor results; the best time for the operation seemed to be July and August, as noted by Garner and Hammond (4). From the original 5 plants 210 had been rooted and potted-on by the end of 1956. Twenty-four plants, including the original five, were kept as stock plants during 1957, and further batches of cuttings were taken on July 9th, 29th, August 2nd, 14th 19th and 27th, September 4th and 13th. Again the earlier batches rooted best. At the end of the second season the 24 plants had been multiplied to over 800, a number which represented approximately 50% of all mature and immature cuttings taken. This percentage would have been considerably improved if the immature cuttings had been rejected.

Some of the early batches of cuttings grew so well after rooting that they required potting-on; for this John Innes potting compost was used. It was often possible to tip-layer the extension shoot and so further increase the number of rooted plants (Fig. 4). By the following spring, after a thorough hardening-off, the plants were large enough to be planted in their permanent quarters instead of being bedded in the nursery for a further season.

To reduce the chance of virus infection during this two-year period the stock plants and the young leaf-bud cuttings were sprayed at intervals of three weeks with metasystox to control insects that might possibly be carrying virus.

A stoolbed of this new virus-tested clone has now been established to supply bedded loganberry plants to nurserymen through the Nuclear Stocks Association, and it is expected that plants will be distributed in limited quantities in the spring of 1959. A half-acre fruiting block was planted at Long Ashton in the spring of 1958. From this it is hoped to gain information on the field cropping qualities and data on cultural practices.

Acknowledgments.

Thanks are due to Dr. A. Beryl Beakbane for her co-operation in the re-issue of this loganberry stock to commerce ; to Messrs. C. S. Gundry and J. S. Coles for help in propagation, and to Messrs. G. H. Jones and D. E. Aliband for the photographs.

REFERENCES.

- (1) BEAKBANE, A. B. (1941). Studies of cultivated varieties of *Rubus* and their hybrids : II. Description and selection of clonal races of some cultivated blackberries and hybrid berries including loganberries. *J. Pomol.* **18**, 368-378.
- (2) BEAKBANE, A. B. (1939). Trials of loganberries, blackberries and hybrid berries. *Ann. Rep. E. Malling Res. Sta. for 1938*, 213-17.
- (3) STOUTEMYER, V. T., MANEY, T. J. and PICKETT, B. S. (1933). A rapid method of propagating raspberries and blackberries by leaf-bud cuttings. *Proc. Amer. Soc. hort. Sci.* **30**, 278-82.
- (4) GARNER, R. J. and HAMMOND, D. H. (1939). "Leaf-bud" propagation of loganberry, youngberry and blackberries. *Ann. Rep. E. Malling Res. Sta. for 1938*, 218-22.

THE CONTROL OF BINDWEED IN BLACK CURRANTS.

By L. C. LUCKWILL and A. I. CAMPBELL.

Introduction.

Two species of bindweed occur in black currant plantations in this country, the small-flowered Field Bindweed (*Convolvulus arvensis* L.) and the larger-flowered Greater Bindweed (*Calystegia sepium* L.). The former, a common weed of arable land, appears to be more prevalent than the latter and there are probably few currant plantations in which this weed is not present to some extent. The Greater Bindweed is more local in its occurrence ; it is primarily a weed of the hedgerows and its presence in a plantation often marks the site of a former hedge. The chief method of propagation of both species is by means of underground rhizomes, which may penetrate to considerable depths, though *Calystegia* can also spread by means of tip rooting of the axillary shoots in the summer. The part played by seeds in the propagation of these weeds is not known, but it is probably a relatively minor one.

The black currant plantation offers an ideal habitat for the bindweeds which, if not checked, can quickly smother and severely weaken the bushes. Eradication by cultivation is virtually impossible on account of the stooled habit and shallow rooting of the black currant, and the most that can be done is to keep the weed in check by constant hoeing of new shoots as they appear beneath the bushes, accompanied by manual removal of shoots in the centre of the bush which escape the hoe. Four or five such cultivations are normally required to keep the bushes reasonably clear during the growing season and, where extensive acreages are infested, the expense involved is naturally very considerable, and may well form an economic barrier to the growing of this crop. This is a situation where chemical methods of weed control would seem to offer the only hope of a solution.

PLATE IV.



Fig. 1.—Preparation of leaf-bud cutting.



Fig. 2.—Callus and young roots on cuttings 3-4 weeks old.



Fig. 3.—Cuttings after 2 months.



Fig. 4.—Cutting taken in July; tip-layered in September.

The hormone type herbicides are ideal for the destruction of bindweed because of the ease and rapidity with which they are translocated within the plant, enabling them to reach the underground parts within a few hours of application, thereby greatly reducing the chances of regeneration. Bindweed has long been known to be susceptible to sprays of 2:4-D and MCPA, particularly at the stage just before flowering, but early attempts to control the weed with these chemicals in black currants were unsuccessful on account of the extensive damage caused to the currants.

More recently MCPB (2-methyl:4-chloro-phenoxybutyric acid) has been used on a small scale for the same purpose. This compound is itself inactive as a herbicide, but it can be converted within the tissues of the plant to MCPA (2-methyl:4-chloro-phenoxyacetic acid), which is then able to exert its herbicidal effects (1). The breakdown to MCPA is brought about by a specific enzyme capable of oxidizing the butyric acid side-chain of the MCPB molecule. The tissues of the two bindweed species appear to be rich in this enzyme compared with those of the black currant so that the degree of selectivity achieved is much greater than with 2:4-D.

MCPB is, however, by no means inactive on black currants. Bushes sprayed to run off with 1,000 parts per million of this compound in June were found to develop very extensive contortions in the new growth, followed by death of the shoot tips. When sprayed at this stage, therefore, great care has to be taken not to wet the young growth. When sprayed later in the season, after the fruit has been picked and when extension growth is almost complete, the visible damage from this compound is less severe and is manifested chiefly as a strong reflexing of the petioles and laminae of the younger leaves. It is probable, however, that when sprayed at this stage, the MCPA formed within the tissues is translocated to the resting buds, as occurs with other woody plants, with the result that damage may show up in the following growing season. Trials with MCPB are not yet advanced enough to assess the importance of this possibility, but it is clear that before general recommendations for the use of this herbicide on black currants can be made, long term trials of its effect on growth and yield will be necessary.

2:4:5-TB (2:4:5-trichlorophenoxybutyric acid) is a related compound whose herbicidal activity also depends on the presence in the plant tissue of a specific β -oxidase. During the course of preliminary trials of a range of phenoxy butyric acids against various fruit plants, carried out at Long Ashton in 1956 (2), it was discovered that this compound alone, of all those tested, produced virtually no damage when sprayed on to black currant bushes at a concentration of 1,000 parts per million in June. Subsequent experiments showed that the Greater Bindweed was readily killed when sprayed with 2:4:5-TB at this concentration. It appeared, therefore, that this compound might prove to be an ideal herbicide for this particular combination of crop and weed; hence in 1957 four further small scale field trials were carried out. These trials, which are reported below, were chiefly against the Field Bindweed, though some plots infested with Greater Bindweed were also included.

Experimental.

Trial 1. Rate of application.

2:4:5-TB was applied as the potassium salt at 500 p.p.m., 1,000 p.p.m. and 1,500 p.p.m. in a plantation of 9 year old Baldwin black currants planted

3 ft. $\times$ 8 ft. Application was made in late July a few days after the fruit had been picked. Despite regular hoeing until picking time only the alleyways were clear of Field Bindweed, which formed a thick carpet under the bushes and also in many places completely covered them.

The experiment was laid out in eight randomized plots, each of six bushes, each treatment being applied to two plots. Two of the eight plots served as untreated controls and were not cultivated until the completion of the experiment. The spray solution was made up without wetting agent in rain water, to avoid the possibility of precipitation of the insoluble calcium salt of 2:4:5-TB by hard tap water; it was applied by means of a knapsack sprayer at the rate of 5 litres per plot (300 gallons per acre). An attempt was made to wet as much as possible of the bindweed foliage on and below the bushes. The weather at the time of application was cloudy and the air temperature was 60°F.

Trial 2. Rate of Application.

Treatments were similar to those of Trial 1 and were applied at the same time and under similar conditions on another site. The bushes were 5 year old Baldwin black currants planted 3 ft. $\times$ 8 ft. and heavily infested with Field Bindweed. In addition some bushes were infested with Greater Bindweed; these were treated as separate units.

Trial 3. Varietal Resistance.

2:4:5-TB was applied to a wide range of black currant varieties during early August. These young stool bushes, not infested with bindweed, were sprayed at 1,000 p.p.m. in order to investigate possible variations in varietal resistance. One litre of spray material was applied per bush to the following varieties: Amos Black, Baldwin, Blacksmith, Cotswold Cross, Malvern Cross, Mendip Cross, Wellington XXX, Westwick Choice.

Trial 4. Effect of Spray Volume.

Treatments were applied at the same time as those of Trial 3 to 6-year-old bushes of Baldwin, Cotswold Cross and Mendip Cross, planted 3 ft. $\times$ 8 ft., among which Field Bindweed was beginning to spread. The treatments were 2:4:5-TB at 1,000 p.p.m. and 1,500 p.p.m. applied at 150 gallons per acre, i.e. half the volume employed in Trials 1 and 2.

Results.

In all the trials the bindweed showed no symptoms of damage during the first week after spraying. 2-3 weeks after spraying flowering stopped, and the young flower buds and shoot tips died. Further examination of Trials 1 and 2 eight weeks after spraying showed that all the growth above ground of the Field and Greater Bindweed had been killed and that the stems had died back to at least 4" below ground level. All three treatments produced similar effects, but the 500 p.p.m. treatment appeared to have killed the bindweed to a depth of only 2 or 3". Similar results were obtained on both species of bindweed.

No damage was seen on any of the black currants in these trials or on any of the wide range of varieties in trial 3. 2:4:5-TB was highly selective in its action and none of the other weeds growing among the bushes, including

Procumbent Speedwell (*Veronica agrestis*), Creeping thistle (*Cirsium arvense*), Groundsel (*Senecio vulgaris*) and *Geranium molle*, was affected by the spray.

Trial 4 was unsuccessful, for although the bindweed was severely checked, the top growth was not completely killed. It would seem that, at the concentrations used, 150 gallons per acre is insufficient to kill the bindweed in early August.

Summary.

Four field trials are described in which the potassium salt of 2:4:5-trichlorophenoxybutyric acid (2:4:5-TB) was used as a herbicide for the control of Field Bindweed (*Convolvulus arvensis* L.) and Greater Bindweed (*Calystegia sepium* L.) in black currants. Good control of both bindweed species was obtained by the application of this compound at 1,000 p.p.m. using 300 gallons per acre, shortly after the crop had been harvested. Black currants are more tolerant of 2:4:5-TB than of MCPB, and at the rates of application used no damage was caused to a wide range of commercial varieties.

Acknowledgments.

The authors are indebted to Messrs. May and Baker Ltd., and to the Mirvale Chemical Co., for the supply of 2:4:5-TB used in these experiments. They also wish to thank the growers who co-operated in these trials.

REFERENCES.

- (1) WAIN, R. L. (1955). A new approach to selective weed control. *Ann. appl. Biol.*, **42**, 151-157.
- (2) LUCKWILL, L. C. and CAMPBELL, A. I. (1957). The tolerance of fruit crops to certain selective and pre-emergence herbicides. *Proc. 3rd Brit. Weed Control Conf.*, 1956, 539-542.

SOIL CONDITIONERS: II. THE EFFECT OF HPAN AND VAMA ON THE YIELD OF STRAWBERRIES.

By C. BOULD.

A previous paper by Bould and Tolhurst (1) dealt with the effect of the sodium salt of hydrolysed polyacrylonitrile (HPAN) and the calcium salt of vinyl acetate maleic acid co-polymer (VAMA) on soil nutrient availability. HPAN was found to have no effect on exchangeable soil potassium or magnesium when used over the range 0.05 to 0.2% on a dry soil basis, but it increased the availability of soil phosphate as determined by the Neubauer rye seedling method. VAMA had no significant effect on the uptake of potassium or phosphate.

The present paper deals with two field experiments carried out at Long Ashton to test the effect of HPAN and VAMA on the yield of strawberry, *var.* Climax, and a field experiment with soil conditioners, including VAMA, carried out at the N.A.A.S. Efford Experimental Horticulture Station with the variety Royal Sovereign.

Experimental.

LONG ASHTON.

The soil on which both experiments were carried out is a reddish-brown heavy sand (Series No. 6 as classified by Osmond (2)) and "caps" badly after heavy rain.

Experiment I. 1952.

Material. Strawberry, *var.* Climax, planted on April 1st, 1952, at 36" between rows and 18" between plants.

Layout and treatments. The layout consisted of seven randomized blocks, each of four plots. Plot size was approximately 0.004 acre and each plot contained 24 recorded plants.

The treatments were :—

1. Control, no fertilizer or HPAN.
2. HPAN at 0.1%, based on the top 3" of soil.
3. Inorganic fertilizers (NPK) at the following rates :—
 Nitro-chalk at 3 cwt. p.a.
 Superphosphate at 4 cwt. p.a.
 Potassium sulphate at 1 cwt. p.a.
4. HPAN + NPK as in 3.

The HPAN was broadcast on the surface and roto-tilled into the top 3" of soil, but it picked up moisture so rapidly that uniform mixing was impossible.

Management. As in commercial practice. Plants were de-blossomed in 1952 and the first crop was taken in 1953.

Experiment II. 1953.

Material. Strawberry, *var.* Climax, planted on March 26th, 1953, at 34" between rows and 19" between plants.

Layout and treatments. The design comprised two 4×4 Latin Squares giving eight replicates of four treatments. Each plot was approximately 0.002 acre and contained 12 recorded plants.

The treatments were similar to those in Experiment I, except that VAMA was used instead of HPAN. It was mixed with three parts of talc to facilitate uniform application. VAMA is not so hygroscopic as HPAN, and a fairly uniform distribution was obtained by applying half quantities at a time followed by rotavation. The fertilizers were mixed and applied with the second dressing.

Management. As in commercial practice. The plants were de-blossomed in 1953 and the first crop was taken in 1954. Owing to the rapid development of June Yellows, and the subsequent death of many plants, a second crop was not taken.

N.A.A.S. EFFORD, 1954-7.

This experiment was designed to compare the effect of dung and inorganic NPK on the growth and yield of strawberry in the presence and absence of a synthetic soil conditioner (VAMA) and a natural conditioning agent (Italian ryegrass).

Soil. The soil is a fine sandy loam of a Brickearth type with a tendency to "cap" after rainfall because of the high content of fine sand and silt. Originally very acid, it was dressed with 2 tons p.a. of a magnesian limestone in the season prior to planting. Chemical data pertaining to this soil are given in Table I.

TABLE I.

CHEMICAL ANALYSIS OF EFFORD SOIL (0-8").
(Means of 6 plots as % air-dry soil, 1953).

pH		Organic carbon	P ₂ O ₅ sol. in :		Exchangeable K
1953	1954		1% Citric acid	N/2 Acetic acid	
3.5	5.7	1.31	0.010	0.0026	0.010

Material. Strawberry, *var.* Royal Sovereign, planted 22nd September, 1954, at 36" between the rows and 18" between plants.

Layout and treatments. The layout consisted of six randomized blocks each of six plots. A plot measured 27' × 12' and contained four rows of fifteen plants, the centre two rows only being recorded. Total area = 0.36 acre.

The six treatments were :—

<i>Treatments during 1954 and prior to planting</i>				<i>Annual treatment, 1955-57.</i>
A.	Fallow			NPK in February
B.	Fallow, dung at 20 t.p.a. applied May-June, 1954, and ploughed in			Nil.
C.	Fallow, VAMA applied September, 1954			NPK „ „
D.	Fallow, dung as for B plus VAMA as for C			Nil.
E.	One year ley, sown August 1953, and ploughed under in June, 1954			NPK „ „
F.	One year ley as for E plus dung as for B			Nil.

The soil conditioner (VAMA) was applied to a strip 6' wide so as to include only the two experimental rows from each plot, and roto-tilled to a depth of 6". The rate of application was based on treating the top 6" of soil with 0.05% VAMA and required 6.88 lb. of the formulated VAMA compound, Krilium-631, per 100 sq. ft.

The ley consisted of Italian ryegrass sown in August, 1953, at the rate of 45 lb. per acre. A top-dressing of Nitro-chalk was given in the spring of 1954.

Fertilizers were applied at the following rates :—

N=ammonium sulphate (20%N) at 3 cwt. p.a.

P=superphosphate (18%P₂O₅) „ 4 „ „

K=potassium sulphate (45%K₂O) at 2 cwt. p.a.

In 1954, one half of the PK fertilizer was applied prior to planting ; the remainder, together with the N, was applied as a side dressing in the following February. In subsequent years NPK was applied in February only.

Management. So far as possible management, including pest and disease control, conformed to commercial practice. Virus infected plants in the first year of the trial were recorded, removed and replanted. Subsequently infected plants were removed but not replanted. This necessitated a co-variance correction for weak and missing plants.

Grading of fruit. The fruit was classified into three grades : I. Sound, medium sized to large fruits (½lb. punnet trade) ; II. Sound small fruits (jam size) ; and III. Waste, damaged by slugs and disease-infected.

Results.

LONG ASHTON.

The effect of treatments on total crop and yield of Grade I fruit was not significant in either experiment. Total yields are summarized in Table II, and Table III shows the mean chemical status of leaf samples taken at the time of fruit picking.

TABLE II.

EFFECT OF TREATMENTS ON TOTAL YIELD OF FRUIT : LONG ASHTON.

(Mean yield in lb. per 100 plants, *var.* Climax).

Experiment 1.

Experiment 2.

NPK	HPAN		Response to HPAN	NPK	VAMA		Response to VAMA
	0	1			0	1	
0	170	166	—4	0	129	130	+1
1	163	161	—2	1	132	129	—3
Response to NPK	—7	—5		Response to NPK	+3	—1	

100 lb. $\equiv$ 4.32 tons per acre.

TABLE III.

MEAN CHEMICAL COMPOSITION OF STRAWBERRY LEAVES : LONG ASHTON.

(As % dry matter, sampled 3-7-54).

Total			Treatment			
			Control	NPK	VAMA	NPK+VAMA
Nitrogen	..	..	2.31	2.33	2.52	2.51
Phosphorus	..	..	0.216	0.221	0.228	0.251
Potassium	..	..	1.79	1.76	1.78	1.88

EFFORD.

A general summary showing the effect of treatments on total crop and yield of Grade I fruit for the seasons 1955-57, with co-variance correction for weak and missing plants, is given in Table IV.

TABLE IV.

YIELD OF FRUIT : EFFORD.

Treatment	Mean Yield, lb. per plot ⁺					
	1955		1956		1957	
	Total	Grade I	Total	Grade I	Total	Grade I
(A) NPK ..	4.60	2.48	32.33	17.56	40.53	20.15
(B) Dung ..	4.85	2.68	31.47	17.08	44.56	20.70
(C) VAMA+NPK	3.62	2.07	33.09	17.49	39.14	18.35
(D) VAMA+Dung	4.63	2.68	33.33	18.66	42.67	21.97
(E) Ley+NPK ..	4.58	2.57	30.49	16.65	41.06	19.07
(F) Ley+Dung	5.13	2.87	32.01	19.09	44.58	24.50
Sig. diff. 5%* ..	0.89	0.65			3.72	2.34
„ „ 1%** ..	1.21				5.04	3.17
Remarks	**B,F>C *F>C * E,A,D>C		N.S.	N.S.	**B,F>C * B,F>A	**D>C; F>E

⁺Originally 30 plants ; co-variance correction for weak and missing plants.

1955. Treatments had a significant effect on total crop and yield of Grade I fruit. In the presence of NPK, Krilium reduced significantly the total yield of fruit, but the reduction in Grade I fruit was not significant. The overall effect of dung (treatments B, D and F) on total crop was significantly greater (5% level) than that of NPK (treatments A, C and E), but the overall effect on Grade I fruit just failed to be significant.

1956. Treatment effects were not significant.

1957. Treatments had a significant effect on total yield and yield of Grade I fruit. Total yield from dung plots (B and F) was significantly greater than from plots receiving NPK only, or from plots receiving NPK+Kriliium. Ley reduced slightly the differential effect between dung and NPK, with respect to total yield of fruit, but enhanced the effect of dung on yield of Grade I fruit.

TABLE V.

FRUIT SIZE AND PLANT VIGOUR : EFFORD.

(Fruit size : mean of 4 samples $\times$ 5 sampling dates).

(Vigour : mean of 6 replicates).

Treatment	NPK	Dung	VAMA + NPK	VAMA + Dung	Ley + NPK	Ley + Dung
No. of fruits per $\frac{1}{2}$ lb.	22	22	20	21	20	22
Plant vigour, 21-5-57	3.0	1.1	2.1	1.1	2.5	1.5

(Vigour : 1 = weak ; 2 = medium ; 3 = strong).

Table V shows the effect of treatments on fruit size and plant vigour during the final cropping season, 1957. The average number of fruits per $\frac{1}{2}$ lb., on five sampling dates between the 12th and 24th June, varied very little with treatment. Plant vigour, which was directly related to nitrogen status, was greatest on NPK plots, intermediate on plots receiving soil conditioner+NPK and ley+NPK, and least on plots receiving dung.

Discussion.

Although both HPAN and VAMA had a beneficial effect on soil structure, and increased the stability of soil aggregates, they had no significant effect on the growth and yield of fruit from strawberries grown at Long Ashton, or on leaf nutrient status as determined at the time of fruit picking. The leaf nutrient status, as shown in Table III, was satisfactory with respect to N, P and K and, apart from June Yellows, no other factor appeared to be limiting growth. It would seem, therefore, that the structure of the untreated soil was sufficiently good for normal root growth and uptake of plant nutrients.

At Efford, applications of VAMA definitely improved soil structure and the stability of soil aggregates. This was particularly noticeable after the winter rains : untreated soil capped badly, and many plants were silted over in the first season. Despite the beneficial effect on soil structure VAMA did not enhance the response either to inorganic fertilizer or to dung, and it reduced the yield of fruit in 1955 and 1957. This may have been due to slight toxicity effects, or more probably to some effect on the water régime of the soil. Over the three seasons general plant growth and crop yield on all plots were good.

The ryegrass ley had no significant effect on the subsequent response to NPK, but in 1957 the total weight of Grade I fruit on ley+dung plots was significantly higher than on dung only plots. The growth of the ryegrass was rather poor and its contribution to the soil organic matter was probably very small. There was a small but significant response to dung as compared with plots receiving NPK, or NPK+VAMA. Since the soil structure and nutrient supply on NPK+VAMA plots were good the additional response to dung may have been due to its effect on available water supply.

These experiments indicate that synthetic soil conditioners are not an economic proposition for strawberry growing and that dung is more effective and cheaper.

Summary.

The effects of two synthetic soil conditioners, HPAN and VAMA, on the growth and yield of strawberries in three field experiments are described. Both compounds had a beneficial effect on soil structure and soil aggregate stability without enhancing the yield of fruit either in the presence or absence of inorganic NPK fertilizers.

Acknowledgments.

The author is indebted to Mr. E. Catlow for the management and recording of the two field experiments at Long Ashton; to Miss H. M. Hughes and Mr. O. S. Welford for similar assistance at Efford; to Mr. T. N. Hoblyn and Mr. G. M. Jolly for the design and layout of the Efford experiment, and to Mr. G. M. Clarke for the statistical analysis of the field results. Thanks are also expressed to Mr. P. H. Brown, Director of the Efford Station, for his interest and help, and to Monsanto Chemicals Ltd., for supplying the synthetic soil conditioners.

REFERENCES.

- (1) BOULD, C. and TOLHURST, J. (1953). Soil conditioners: I. The effect of the sodium salt of hydrolysed polyacrylonitrile (CRD 189) and of CRD 186 on nutrient availability and uptake by plants. *Ann. Rep. Long Ashton Res. Sta. for 1952*, 55-62.
- (2) OSMOND, D. A. (1937). *Ann. Rep. Long Ashton Res. Sta. for 1936*, 256.

SPRAY APPLICATION PROBLEMS: XLII. MERCURY DEPOSITS ON APPLE FRUITS AND FOLIAGE.

By J. T. MARTIN and J. A. PICKARD.

Introduction.

Fungicidal sprays containing organo-mercury compounds have been used increasingly in recent years for crop protection purposes in this country. Compounds such as phenylmercuric chloride or nitrate are applied pre- and post-blossom in orchards in the form of water suspensions, or may be used under

glass as aerosols or vaporizing solutions. Treatment is often made at a time when fruits are developing and some concern has been felt that consumer hazards may result from the ingestion of contaminated crops.

The toxicological position is difficult to assess since few data have been published in this country on the levels of mercury contamination of crops at harvest time. Miller (1) has reported that apples harvested twelve weeks after the last applications of the commonly-used orchard sprays showed residues equivalent to up to 0.07 p.p.m. of metallic mercury (Hg). Beidas and Higgons (2) have shown that glasshouse tomatoes treated with aerosols may contain 0.5 p.p.m. Hg, the contamination occurring chiefly in the pulp, with potential risk to the consumer. Aryl mercury compounds such as phenylmercuric nitrate are less harmful to mammals than other forms of mercury but may change to more toxic derivatives when exposed on plants. The consumer risk cannot therefore be fully assessed until information is available not only on the levels of contamination, but also on the chemical form in which the mercury persists on or in plant tissues.

An orchard trial using phenylmercuric nitrate was carried out at Long Ashton during the summer of 1957 to follow the possible build-up of mercury in Bramley apple leaves and fruits. Bramley apples taken from the store of a commercial fruit farm in Somerset which had used a phenylmercury spray programme during 1957 were also examined for mercury residues. This article gives a brief description of the trials, the analytical methods and results ; a full report will be published elsewhere.

Experimental.

Materials and method of application.

A row of sixteen Bramley's Seedling half-standard trees not subject to spray drift from other experiments was used for the Long Ashton trial ; their average height was 13 ft. and their average spread 20 ft. Trees 1-11 were sprayed and 12-16 were kept unsprayed as controls. Samples for analysis were taken only from the sprayed trees 1, 5, 9, and 11 and from the control tree 14. Leaf and fruit samples were taken at random from the top, centre and lower periphery of each tree.

A proprietary phenylmercuric nitrate dispersible powder containing 1.58 per cent. of organically-combined mercury, diluted 2 lb. per 100 gal. (0.003 per cent. Hg) was applied at an average rate of 5.6 gal. of diluted wash per tree to ensure complete wetting. Seven applications were made extending from the green cluster stage to within eight weeks of harvest. Samples were taken for analysis immediately before spraying and soon after the deposit had dried. Fruits first became available for examination at the time of the fourth application.

The trees at the commercial fruit farm also received seven applications of phenylmercuric nitrate : the first, on 28th March, 1957, at 0.003 per cent. Hg and the remainder, over the period up to 23rd July, at 0.002 per cent. Hg.

The methods of analysis.

In our work on spray deposits an attempt is made, so far as possible, to distinguish between the spray chemical remaining on the surface and that absorbed within the plant tissue. Some idea of the localisation of the mercury

contamination of apple fruits may be obtained by the examination of peel and flesh, using the acid digestion method of Klein (3) as modified by Abbott and Johnson (4). For the leaves, solvent washing to remove surface contamination, followed by maceration of the tissues to recover absorbed deposits, is required. Acetone containing a small amount of hydrochloric acid was found to be an effective solvent. Interfering pigments were removed by passing the acidified acetone extracts through powdered cellulose. Treatment of the solutions containing the phenylmercuric nitrate with additional hydrochloric acid at 65°C. permitted both bonds of the mercury atom to take part in the dithizone reaction, which was utilized for the colorimetric determination of the mercury. This method, which is carried out almost entirely at room temperature, proved satisfactory for the determination of surface deposits on leaves and fruits.

Results.

(a) Leaves.

The data obtained from the analysis of leaves from the trees of the Long Ashton trial are shown in Table I. Each value represents the mean of twelve determinations, by the cold extraction method, made on samples from three positions in each of the four trees.

TABLE I.
MERCURY DEPOSITS ON BRAMLEY LEAVES FROM LONG ASHTON TRIAL.

Date	Sample	Hg p.p.m.	
		Surface deposit	Absorbed deposit
3rd April	Before spraying	nil	nil
	After ..	3.8	0.3
16th April	Before ..	0.3	0.1
	After ..	6.3	0.2
21st May	Before ..	1.1	1.1
	After ..	10.0	0.7
11th June	Before ..	1.8	0.7
	After ..	10.6	1.0
4th July	Before ..	2.8	0.7
	After ..	7.4	0.9
24th July	Before ..	1.0	0.7
	After ..	7.4	2.5
8th August ..	Before ..	1.1	1.3
	After ..	4.0	2.9

The maximum values recorded in the examination of unsprayed leaves were : surface deposit 0.15, absorbed deposit 0.21 p.p.m., expressed as Hg.

The results show that no build-up occurred of surface deposits, and that a slight accumulation of mercury had taken place within the leaves.

The results by the cold extraction process were checked by analyses using the acid digestion method. Leaves taken after the application on 24th July were surface-washed and macerated and the residual fibrous material and comparable whole leaves were acid digested. The results are shown in Table II.

The results show that mercury tended to accumulate in the leaf fibres, and that the value obtained by the summation of the amounts present on the surface, in the leaf cellular material and in the fibres, agreed with those given by the digestion of the whole leaf.

TABLE II.
MERCURY DEPOSITS ON BRAMLEY LEAVES BY
COLD EXTRACTION AND ACID DIGESTION METHODS.
Hg p.p.m.

Sample	Cold extraction		Acid digestion		
	Surface deposits	Absorbed deposits	Fibre	Total	Whole leaves
A	7.6	1.7	4.6	13.9	14.6
B	9.2	4.4	4.6	18.2	19.4

(b) *Fruits.*

After the application at Long Ashton on the 11th June, when the fruits were small, surface deposits averaged 0.19 p.p.m. and after the subsequent applications 0.10 p.p.m. Hg. The surface deposits fell to low values between each application. At harvest on 10th October, deposits removable by solvent washing amounted to less than 0.01 p.p.m. and the absorbed deposits to 0.03 p.p.m., equivalent to a total contamination of 7 μ g. Hg per average apple of 200 g. weight.

The total deposits associated with some of the apples from the Long Ashton spray treatment were determined by the acid digestion method, and somewhat higher levels of contamination were found. It seemed likely that the maceration method was failing to recover all the mercury occluded within the cuticle or present in the flesh of the fruits. Apples from the Long Ashton trial, taken from store during the period October, 1957 to February, 1958 were therefore peeled and mercury determined separately on peel, flesh and core by the acid digestion method. The results, subtracting determinations on blanks, are shown in Table III.

TABLE III.
MERCURY DEPOSITS (AS Hg) ON BRAMLEY FRUITS FROM LONG ASHTON TRIAL :
ACID DIGESTION METHOD.

Sample	Peel p.p.m.	Flesh p.p.m.	Core p.p.m.	Total p.p.m.	μ g. per 200 g. apple
A	0.08	0.14	0.03	0.12	25
B	0.08	0.06	0.02	0.06	12
C	0.06	0.02	0.02	0.02	4
D	0.17	0.05	0.01	0.06	11
E	0.14	0.05	nil	0.05	10
Mean	0.11	0.06	0.02	0.06	12
Control	0.014	0.010	0.005	0.01	2

Tests were also made on the Bramley apples from the commercial fruit farm, taken from store in February, 1958. The results, allowing for blanks, are shown in Table IV.

TABLE IV.

MERCURY DEPOSITS (AS Hg) ON BRAMLEY FRUITS FROM COMMERCIAL FARM :
ACID DIGESTION METHOD.

Sample	Peel p.p.m.	Flesh p.p.m.	Core p.p.m.	Total p.p.m.	µg. per 200 g. apple
F	0.15	0.01	0.02	0.02	3
G	0.08	0.09	0.01	0.09	19
H	0.22	0.02	0.04	0.04	7
I	0.06	0.02	0.02	0.02	5
Mean	0.13	0.04	0.02	0.04	9

The results in Tables III and IV indicate that Bramley apples subjected to phenylmercuric sprays under commercial conditions may be expected to show a level of contamination of 0.05 p.p.m. Hg, equivalent to 10 µg. Hg per average-sized apple. Furthermore a significant proportion of this contamination occurs in the flesh of the fruits.

Satisfactory recoveries were obtained when known amounts of mercury, as phenylmercuric nitrate, were added to apple fractions before acid digestion.

The effect of cooking on the retention of mercury by apple fruits.

Some of the apples from the Long Ashton trial were oven-baked, after coring and adding sugar, to ascertain whether the mercury was lost or retained in cooking. Mercury was found in the peel (0.06 and 0.07 p.p.m.) and flesh (0.03 and 0.07 p.p.m.) after cooking, but none was detected in the syrup.

The form in which the mercury persists on the fruits.

The dithizone complex of phenylmercuric nitrate or chloride shows maximum absorption at 475 mµ whereas the complex with inorganic mercury shows maximum absorption at 490 mµ. Bramley fruits were sprayed in October with the nitrate and chloride, each at 0.2 per cent. After 7–12 days, the deposits were washed off and the complexes formed. These showed absorption maxima of 475 mµ; after treatment of the extracts with acid at 65°C, absorption maxima were 490 mµ. The results indicate that after exposure on fruits for a limited period towards the end of the season, phenylmercuric nitrate and chloride remain unchanged in chemical form. Further tests, however, are required earlier in the season when the fruits are subjected to higher temperatures and bright sunlight.

Discussion.

Sufficient replicate analyses of leaves were carried out to give an indication of the mean levels of deposits at different positions in the trees. Despite the use of a drenching spray and every care to obtain full coverage, deposits in the tops were invariably lower than those in the centres or lower peripheries of the trees.

Despite considerable variations in the deposits, particularly on fruits, in samples taken at any one time a general impression of the levels of contamination and losses on weathering may be obtained. If Bramley foliage and fruits are well wetted, a phenylmercuric nitrate spray fluid at 0.003 per cent. Hg will

deposit 10–20 p.p.m. Hg on the leaves, about 0.2 p.p.m. Hg on small fruits and about 0.1 p.p.m. on larger fruits. Some of the mercury of these surface deposits passes into the leaves and fruits, and much of the remainder is lost fairly rapidly by weathering. Within the leaves, mercury is found in the cellular tissue and in close association with the fibres. Of the mercury that passes into the fruits, some is located in the cuticular layer and an appreciable proportion is present in the flesh. The net effect of the weathering of the surface deposits and the retention of some of the mercury within the fruits is to reduce the total level of contamination of 0.1 p.p.m. or more after the last application to something of the order of 0.05 p.p.m. Hg at harvest time. This value is in good agreement with those reported by Miller (1).

The significance of the residues of mercury found in the apples taken from store is better appreciated if the p.p.m. values for the peel, flesh and core are translated into micrograms of mercury present in these fractions. A Bramley's Seedling apple of 200 g. weight is made up of approximately 15 g. of peel, 170 g. of flesh and 15 g. of core. On the basis of the mean values for the Long Ashton and commercial apples reported in Tables III and IV, the peel of an average-sized apple contains 2 $\mu\text{g.}$, the flesh 8 $\mu\text{g.}$ and the core less than 1 $\mu\text{g.}$ Hg. The toxicological significance of these levels of contamination, which persisted to some extent after baking the fruits, has yet to be determined.

Summary.

The mercury deposits on Bramley's Seedling apple leaves and fruits, following seven applications of phenylmercuric nitrate at 0.003 per cent. Hg, were followed throughout the season. Surface deposits were largely lost from leaves and fruits between each application but some penetration of mercury into the leaves and fruits occurred.

Sprayed fruits taken from store showed a mean level of contamination of mercury of 0.05 p.p.m., equivalent to 10 micrograms of mercury per apple of 200 grams weight. Of this amount, 2 micrograms occurred in the peel, 8 micrograms in the flesh and less than 1 microgram in the core of the fruit.

Mercury was present in the peel and flesh after baking the fruit.

Acknowledgments.

We are indebted to Mr. C. W. Harper for the application of the sprays and to Mr. G. M. Clarke for the analysis of results.

REFERENCES.

- (1) MILLER, E. J. (1956). *Plant Pathology*, **5**, 119–121.
- (2) BEIDAS, A. S. and HIGGONS, D. J. (1957). *J. Sci. Fd Agric.*, **8**, 597–600.
- (3) KLEIN, A. K. (1952). *J. Ass. off. agr. Chem.*, **35**, 537–542.
- (4) ABBOTT, D. C. and JOHNSON, E. I. (1957). *The Analyst*, **82**, 206.

SPRAY APPLICATION PROBLEMS : XLIII.

NOTE ON THE PREPARATION OF BORDEAUX MIXTURE.

By E. SOMERS,

Introduction.

Bordeaux mixture, obtained by the interaction of a solution of copper sulphate and a suspension of calcium hydroxide, is widely used in plant protection, but after sixty years of practical application some doubt still exists as to the best method of preparing the material. Bedford and Pickering (1) recommended the addition of a concentrated copper sulphate solution to the diluted lime, while Butler (2) found that the most suitable precipitation was obtained by mixing equal strengths of copper and lime or by the addition of diluted copper to concentrated lime. Holland, Dunbar and Gilligan (3) examined twelve methods of preparation and concluded that dilute copper should be added to concentrated lime or equal volumes of reactants should be used. These recommendations were based on studies of the sedimentation rates of Bordeaux mixtures. The influence of the physical properties of the Bordeaux precipitate, which are known to vary with the method of preparation, on its fungitoxicity and tenacity on foliage was not considered, although these properties determine the effectiveness of the fungicide in the field. This note summarizes the findings on sedimentation, crystallization, tenacity and fungitoxicity of Bordeaux mixtures prepared in different ways. A full report will be published elsewhere.

Experimental.

Preparation of the mixtures.

The Bordeaux mixtures were prepared from copper sulphate and carbonate-free calcium hydroxide, both of laboratory grade, or from copper sulphate and quicklime. The calcium hydroxide and quicklime were wetted and ground into smooth pastes just before the mixtures were made.

The amounts of reactants used were 8 g. $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, 10 g. $\text{Ca}(\text{OH})_2$ and 1,000 ml. water (8:10:100 Bordeaux). Mixtures were prepared using different proportions of water carrying the copper sulphate and lime as follows :

Relative volumes

A. Concentrated copper solution added to dilute lime suspension	4:96
B. Copper solution added to lime suspension, equal volumes	50:50
C. Concentrated lime suspension added to dilute copper solution	5:95
D. Copper solution and lime suspension poured simultaneously into third vessel, equal volumes	50:50
E. Lime suspension added to copper solution, equal volumes	50:50
F. Dilute lime suspension added to concentrated copper solution	96:4
G. Dilute copper solution added to concentrated lime suspension	95:5

Sedimentation of the mixtures.

The mixtures, in 100 ml. measuring cylinders, were shaken for 2-3 min. and allowed to settle undisturbed. Distinct differences in sedimentation rates were found. On comparing the times required for the sedimentation volumes to fall 50 per cent., when calcium hydroxide was used $C > E, G > D > B > F > A$ and when quicklime was used $C > E, B > D > G > A, F$.

The preparation methods C and E yielded more slowly sedimenting precipitates than methods A and F, and the precipitates made from slaked quicklime settled more quickly than those from hydrated lime.

Crystallization of the mixtures.

Studies of the crystallization rates of the mixtures were carried out using the method of Burchfield and Schechtman (4). The mixtures were maintained at 40.5°C., aliquots were shaken with 10 per cent. sucrose solution for 2 min., centrifuged and the optical densities of the copper-sucrose chelates measured spectrophotometrically. Methods C and D produced the most slowly, and method G the most rapidly crystallizing precipitates. None of the mixtures showed an induction period before the onset of crystallization.

Tenacity of spray deposits of the mixtures.

The tenacities of deposits of the mixtures were determined on a cellulose acetate surface using the method already described (5) and on potato and broad bean leaves using a more prolonged washing technique. Appreciable differences in the retention of the formulations were seen, with preparation method C yielding the most tenacious deposit.

Fungitoxicity of spray deposits of the mixtures.

The *in vitro* fungistatic activities of spray deposits of the mixtures were determined by the method already described (5) using *Alternaria tenuis* and *Stemphylium sarcinaeforme* as test organisms. The potencies of the deposits were compared with that of the deposit formed by method A. The preparation methods C and D gave spray deposits more fungitoxic than those from method A, this effect being shown in the tests with both fungi. The other preparation methods gave deposits of lower fungistatic activity than A.

Discussion.

The preparation of Bordeaux mixture by the addition of lime in concentrated form (method C) or in a volume equal to that of the copper solution (method D) has been shown to give precipitates of greater efficiency, when judged on sedimentation and crystallization rates and on the tenacities and fungitoxicities of spray deposits, than those formed by the other methods of preparation tested. For practical purposes, the most convenient method is to add one component in a concentrated form to the other already diluted in the spray tank. At present, concentrated copper solution is often added to the diluted lime suspension. It is suggested that this procedure should be reversed and that improved field performance should result if the concentrated lime paste is washed into the diluted copper sulphate.

Acknowledgments.

I am indebted to Mr. D. V. Richmond and Mr. A. J. Sims for experimental assistance and to Mr. G. M. Clarke for the calculation of relative potencies.

REFERENCES.

- (1) BEDFORD, DUKE OF, and PICKERING, S. U. (1910). 11th Rep. Woburn Exp. Fruit Farm, 22.
- (2) BUTLER, O. (1914). *Phytopathology* **4**, 125.
- (3) HOLLAND, E. B., DUNBAR, C. O. and GILLIGAN, G. M. (1927). *J. agric. Res.* **34**, 677.
- (4) BURCHFIELD, H. P. and SCHECHTMAN, JOAN. (1955). *Contr. Boyce Thompson Inst.* **18**, 215.
- (5) SOMERS, E. (1956). *J. Sci. Fd Agric.* **7**, 160.

STUDIES ON THE NATURAL PROTECTIVE COVERING OF PLANTS:

II. THE WAX AND CUTIN OF LEAVES AND FRUITS.

By J. T. MARTIN, R. F. BATT and MARGARET F. ROBERTS.*

The cellular tissue of the aerial portion of a higher plant is covered by a layer of non-living material known as the cuticle. The structure of the cuticle of the leaf has been described by Orgell and van Overbeek (1). It consists of a spongy framework of cutin with occluded and surface wax. Electron microscope studies by Schieferstein and Loomis (2) show that the surface wax may be present as a discontinuous deposit. The cuticular layer overlies the epidermal cells from which it is usually separated by a thin layer of pectin. Plasmodesmata, the protoplasmic strands which interconnect the living cells of the leaf, extend through the pectin layer into the spongy matrix. The cuticle of the apple fruit similarly is composed of a thick layer of cutin impregnated and covered with waxy material.

An account was given in the last report (3) of the importance of the cuticle in relation to the deposition and subsequent behaviour of spray chemicals on plant surfaces and to the infection of leaves and fruits by fungi. The cuticle helps to control the degree of turgidity of the leaf. Under wet conditions the cutin absorbs water and swells, and the pockets of occluded wax are pushed farther apart; when dry, the cutin shrinks, the wax deposits are drawn together and loss of water from the leaf is reduced. Chemicals penetrate the leaf most readily when the cuticle is in the wet, swollen condition and this may help to explain the leaf damage caused by some spray chemicals when application is followed by wet weather. Surface active agents are likely to assist the wetting and subsequent swelling of the cutin and so may promote injury. The risk of spray damage is believed to be greatest when fruit-trees are grown under poor nutritional or unfavourable environmental conditions. Under such conditions, cuticle development may be impaired and the entry of chemicals into the leaf facilitated.

At present little is known of the relative proportions of wax and cutin in the leaf or fruit cuticle, of the stages of development of the plant at which the components of the cuticle are laid down, or of the effect of nutritional and other factors on cuticle formation. Most of the work by other investigators has

* Boots Research Scholar, 1957-9.

been concerned with the waxes of fruits and leaves and this has been summarized elsewhere (3, 4). Legg and Wheeler (5) found that the leaf cuticle of the fibre-yielding plant *Agave rigida* consisted of 55% of cutin, 20% of wax, 15% of cellulose and 10% of water-soluble material. Matic (6) has isolated hydroxylated octa- and hexa-decanoic acids by saponification of the wax-free cutin from leaves of *A. americana* and has shown the similarity of this cutin to suberin, the characteristic component of cork. Markley and Sando in 1933 (7) investigated the progressive changes in the waxy constituents and cutin of the cuticle of apple fruits during growth and storage. The cuticle was separated from the flesh with dilute acid, extracted successively with ether, alcohol and dilute acid and alkali to remove wax and non-cellulosic impurities, and the cutin was determined by loss of weight on saponification of the residue. Huelin and Gallop (8) in similar work have used the weight of ether-soluble acids yielded on saponification of the cutin fraction as a more reliable measurement of cutin content.

A preliminary account of the fractionation of the waxy surface layers of apple leaves and fruits has already been given (3). This article gives a progress report of work on the cuticle-wax of leaves of other species and on the determination of cutin in the cuticle of leaves and fruits.

The Cuticle-wax of Leaves.

The separation of the cuticle-wax uncontaminated by fatty material extracted from within the leaf presented some difficulty. Tests reported elsewhere (4) showed that the most satisfactory method consisted of washing the leaves successively with ether at room temperature.

Extraction of the ether washings with dilute alkali removed acidic material which was recovered by acidification and re-extraction with ether. In this process some of the acidic material remained in solution in the aqueous layer. The water-soluble acids were obtained by taking the aqueous solution to dryness and extracting with dry acetone.

The acid-free ether solution of the cuticle-wax was taken to dryness and steam distilled to remove volatile constituents. These were present only in small amounts, never exceeding 0.02 per cent. of the fresh leaves. The residue after distillation was taken up in ether, and an excess of acetone was added to precipitate the true wax. The oil component of the cuticle-wax remained in solution in the ether-acetone mixture. All fractions were recovered dry and weighed.

In some tests, the order of separation of the components was changed, the true wax being precipitated first, but the results were not materially affected.

The values obtained for the major constituents of the cuticle-wax of different species of leaves are shown in Table I.

Measurements of the total surface areas of the leaves (to include both upper and lower surfaces) permitted assessments of the extent of formation of cuticle-wax. The Worcester and Cox apple leaves showed 47-53, the pear leaves 30-37, the cabbage 35 and the laurel 57 μ g. of cuticle-wax per sq. cm. of leaf surface. The cuticle-wax of the tomato leaf was negligible in amount. An interesting feature was the high proportion of acidic materials in some of the waxy coverings.

TABLE I.

COMPONENTS OF THE CUTICLE-WAX OF LEAVES OF DIFFERENT SPECIES.
(Per cent. of fresh leaves).

	Total cuticle wax	True wax	Ether- soluble wax acids	Water- soluble wax acids	Oil
Apple <i>var.</i> Worcester	0.43	0.03	0.20	0.03	0.09
Cox	0.47	0.04	0.23	0.04	0.07
Bowden*	0.28	0.02	0.26	0.02	0.12
Pear <i>var.</i> Conference	0.34	0.02	0.10	0.02	0.14
Williams	0.50	0.03	0.14	—	0.18
Cabbage <i>var.</i> Ellams Early	0.12	0.05	0.01	0.01	0.03
Tomato <i>var.</i> Vetomold	0.02	<0.02	<0.01	<0.01	<0.01
Laurel	0.41	0.01	0.18	0.03	0.09

* old leaves.

The Cuticle-cutin of Leaves.

In addition to the wax, the most important constituent of the cuticle is believed to be the cutin, composed of condensed long-chain hydroxy acids which may be liberated by saponification. Other compounds are likely to be present in, or closely associated with, the cuticular layer. These include the cellulose of the outer walls of the epidermal cells, lignin, pectin, organic acids and possibly sugars. The method used by us for the determination of cutin in leaves, like those employed by Markley and Sando and by Huelin and Gallop in the examination of apple fruits, aims at the successive removal of these constituents by suitable solvent extraction. The cutin is finally determined in a residual cutin-cellulose mixture by the loss of weight on saponification and by the recovery of the hydrolysed cutin acids. Tests showed that the determination of cutin was satisfactory only when most of the extraneous material was first removed.

Measurements were made of the extent of cutin formation by stripping the wax-free cuticle separately from the upper and lower surfaces of rhododendron and laurel leaves at least one year old. These leaves were chosen for the tests because of their highly cuticularised nature. Orgell (9) employed enzymic removal of the pectic layer to isolate leaf cuticles. We have extracted the pectin chemically with 1.6 per cent. ammonium oxalate in 0.4 per cent. oxalic acid solution.

One hundred leaf discs, each 3 sq. cm. in area, taken from the laminae avoiding the main veins, were exhaustively extracted with ether to remove the wax, and then with methyl alcohol to remove pigments. The discs were then refluxed with the ammonium oxalate solution, after which the cuticles were easily separated by hand from the upper and lower surfaces (the venation characterized the lower surfaces) as thin, translucent films. These were washed and dried to constant weight.

The cutin contents of the stripped cuticles were determined as follows. The discs were refluxed with dilute sulphuric acid, then with dilute potash, washed and dried to constant weight. The residues, consisting essentially of

cutin and cellulose, were then saponified with alcoholic potash for three hours. The solid residue was weighed again to give the dissolved cutin, and the cutin acids were recovered by removal of the alcohol, addition of water, acidification and extraction with ether. Some of the cutin acids were water-soluble, and, as with the examination of the cuticle-wax, these were recovered by extraction of the dried residue with acetone. The results of the tests are given in Table II.

TABLE II.
CUTIN IN CUTICLES ISOLATED FROM THE UPPER AND
LOWER SURFACES OF RHODODENDRON AND LAUREL LEAVES.
(Per cent. of fresh leaves).

		Wax-free cuticles	Ether- soluble cutin acids	Water- soluble cutin acids	Cutin from cutin acids	Cutin from loss on saponifica- tion
Rhododendron						
Upper surface	..	2.4	1.1	0.1	1.2	1.1
Lower	..	2.5*	0.8	0.1	0.9	0.7
Laurel						
Upper surface	..	3.3	1.4	0.2	1.6	2.1
Lower	..	4.1*	0.9	0.2	1.1	1.9

* some attached cellular tissue.

The separated wax-free upper surface cuticles thus contained about 50 per cent. of cutin determined as cutin acids, and slightly more cutin was present in the upper than in the lower surface cuticles.

The procedure used for the determination of cutin in the stripped cuticles formed the basis of a method for cutin in whole leaf discs. Discs of the rhododendron and laurel leaves were treated as above, except that two extractions with dilute acid and three with dilute alkali were made. The results are given in Table III.

TABLE III.
CUTIN IN DISCS OF RHODODENDRON AND LAUREL LEAVES.
(Per cent. of fresh leaves).

		Ether-soluble cutin acids	Water-soluble cutin acids	Cutin from cutin acids	Cutin from loss on saponification
Rhododendron	..	2.4	0.3	2.7	2.5
Laurel		2.6	0.3	2.9	3.0

Further determinations of cutin in the laurel leaves were made by a shortened procedure. The values obtained were: cutin from cutin acids 3.1 and 3.4 per cent., cutin by loss on saponification 3.3 and 3.2 per cent. The results show that the method is reproducible and that determinations of cutin in leaf discs agree reasonably well with those on the isolated cuticles.

Cuticle-wax and Cutin in Leaves and Fruits.

Work on the wax and cutin in the leaves and fruits of apple, black currant and tomato, of different varieties, at different stages of development or under different nutritional and environmental conditions will be reported later. Some idea of the composition of the cuticle of young tomato and black currant (grape stage) leaves and of apple fruits (Cox) taken from storage may, however, be given. The values for the main wax components and cutin, expressed as per cent. of fresh material and $\mu\text{g./sq. cm.}$ of plant surface, are shown in Table IV.

TABLE IV.

COMPONENTS OF THE CUTICLE OF TOMATO AND BLACK CURRANT LEAVES AND APPLE FRUITS.

	Tomato leaf		Black currant leaf		Apple fruit	
	%	$\mu\text{g./sq. cm.}$	%	$\mu\text{g./sq. cm.}$	%	$\mu\text{g./sq. cm.}$
Total waxy deposit	0.02	3	—	—	0.07	760
True wax	<0.01	1	0.08	6	0.03	340
Ether-soluble wax acids	<0.01	1	0.05	4	0.02	230
Oil	<0.01	1	0.22	17	0.01	130
Cutin from cutin acids	0.22	28	0.28	21	0.10	960
Cutin from loss on saponification	0.24	30	0.31	23	0.12	1230

Other comparisons may be of interest. The rhododendron leaves were excessively waxy (over 100 $\mu\text{g./sq. cm.}$) and showed 250 $\mu\text{g.}$ of cutin (from cutin acids) per sq. cm. of surface. The level of cutin in the cuticle of the laurel leaves referred to in Tables II and III was of the order of 480 $\mu\text{g./sq. cm.}$ Smaller and poorer laurel leaves from another site showed 2.1 per cent. cutin from cutin acids (2.2 per cent. by saponification loss), equivalent to 310 $\mu\text{g./sq. cm.}$ Young cauliflower leaves showed 40 $\mu\text{g.}$ of waxy deposit and 8 $\mu\text{g.}$ of cutin on each sq. cm. of leaf surface.

Summary.

The determination of the wax and cutin components of the cuticle of leaves and fruits is described.

REFERENCES.

- (1) VAN OVERBEEK, J. (1956). *Ann. Rev. Plant Physiol.* **7**, 355-72.
- (2) SCHIEFERSTEIN, R. H. and LOOMIS, W. E. (1956). *Plant Physiology*, **31**, 240-47.
- (3) MARTIN, J. T. (1957). *Ann. Rep. Long Ashton Res. Sta. for 1956*, 94-100.
- (4) MARTIN, J. T. and BATT, R. F. (1958). *Ann. appl. Biol.* (in the press).
- (5) LEGG, V. H. and WHEELER, R. V. (1929). *J. chem. Soc.*, 2444-9.
- (6) MATIC, M. (1956). *Biochem. J.*, **63**, 168-76.
- (7) MARKLEY, K. S. and SANDO, C. E. (1933). *J. agric. Res.* **46**, 403-12.
- (8) HUELIN, F. E. and GALLOP, R. A. (1951). *Aus. J. Sci. Res. B* **4**, 526-32.
- (9) ORGELL, W. H. (1955). *Plant Physiology*, **30**, 78-80.

PRELIMINARY TESTS OF POTENTIAL ORCHARD FUNGICIDES.

By R. J. W. BYRDE and NORA M. WAUGH.

The primary requirement of a fungicide to be used in crop protection is the ability to control the principal diseases, at an economic price, without causing host damage or leaving undesirable residues. None of the fungicides in current use on apples fulfils this requirement. For example, lime sulphur gives rise to scorch on certain varieties; captan, which is virtually non-phytotoxic, is ineffective against apple mildew (caused by *Podosphaera leucotricha* (Ell. & Everh.) Salm.); karathane, which controls mildew, is relatively ineffective against apple scab (caused by *Venturia inaequalis* (Cooke) Wint.). There is thus still a need for new materials combining all these qualities.

In order to assess the merits and demerits of a given compound, it must be subjected to field testing over a period of several years. In view of the large number of potential fungicides and the shortage of experimental orchards, some preliminary screening is usually undertaken in the laboratory. This report describes such tests on eleven compounds which, for various reasons, seemed likely candidates for subsequent field trials. These compounds were tested for their ability to inhibit germination of conidia of *V. inaequalis*, and mycelial growth of *Sclerotinia laxa* Aderh. & Ruhl., the cause of blossom wilt diseases and a convenient test fungus. Although it would seem logical to use *P. leucotricha* in the tests, this fungus is unsuitable for rapid screening owing to its inability to grow in culture.

Experimental.

FUNGICIDES.

The following materials were tested :—

(1) *Antibiotics.*

Griseofulvin, a metabolic product of three species of *Penicillium*, which induces marked abnormality of hyphal growth and spore germ tubes in many fungal genera (1). It has been tested in the field against a number of plant pathogens (2).

Nystatin (mycostatin), an antifungal produced by *Streptomyces noursei*, which is extensively used in the treatment of animal mycoses (3), and recently investigated in connection with plant pathogens (4).

Acti-trin, produced by an unidentified species of *Streptomyces* (designated X 5-X) isolated in Malaya by Dr. R. Green. This antibiotic was kindly supplied by Mr. R. C. Codner of the M.R.C. Antibiotics Research Station, Clevedon.

(2) *Phenolic compounds.*

o-Hydroxy-diphenyl, which showed high fungistatic activity in laboratory tests at Long Ashton against *Ceratostomella fimbriata* (Ell. & Halst.) Elliot, the fungus causing mouldy rot of rubber (5).

Bis-(3-chloro-6-hydroxyphenyl) methane ("G-4") and bis-(3-chloro-6-hydroxyphenyl)-2:2:2-trichloroethylidene ("NF-14"), which were among the most potent bisphenolic fungicides tested by Corey & Shirk (6) against *Aspergillus niger*.

Bis-(3-chloro-6-hydroxyphenyl) sulphide ("Cr.305"), which was abandoned in the U.S.A. as a potential scab fungicide because of its tendency to cause fruit russet (7) but was included for comparison with the above phenolic compounds.

(3) *Heterocyclic nitrogen compounds.*

Decamethylene-bis-4-aminoquinadinium chloride ("DAQC") and hexadecamethylene-bis-isoquinolinium chloride ("HQC"), which have been found to be highly active against fungal pathogens of animals (8,9).

2:4-Dichloro-6-(*o*-chloroanilino)-*s*-triazine ("B 622"), which was the most promising of a series of *s*-triazines tested at the Boyce Thompson Institute, U.S.A., against several plant pathogenic fungi (10).

Captan, which was included as a standard in one of the tests.

(4) *Non-heterocyclic nitrogen compound.*

n-Dodecyl-guanidine acetate, a new fungicide of U.S. origin, which was tested in the form of a 70% wettable powder.

FUNGI.

The culture of *S. laxa* was a strain isolated from sour cherry. Stock cultures were maintained on potato dextrose agar.

The culture of *V. inaequalis* was obtained from the Commonwealth Mycological Institute, Kew. Conidia were collected from cultures 3 to 4 weeks old grown on filter paper cylinders dipped in 10% malt extract (11).

METHODS.

(a) *Mycelial growth on agar.*

Fungistatic activity against the mycelium of *S. laxa* was assessed by its growth rate on agar medium in which the compounds under test were incorporated. The medium comprised glucose, 40 g.; peptone, 10 g.; KH_2PO_4 , 6.8 g.; $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, 2.5 g.; CaCl_2 , 0.1 g.; FeCl_3 , 0.02 g.; agar, 30 g.; water to 1 litre.

The medium was dispensed in 50 ml. lots in 100 ml. flasks, autoclaved at 10 lb./in² for 20 min. and held at 45°–50°C. in a water bath. The compounds were incorporated as ethyl alcoholic solutions of appropriate concentration by means of a sterile pipette; the final concentration of ethyl alcohol in the medium was adjusted to 1% throughout.

Four replicate petri dishes were poured from each of the flasks, which included a control. On cooling, the plates were inoculated at a central point with a 4.5 mm. disk cut from a 3-day-old culture of *S. laxa*, and incubated at 25°C. Mycelial growth along two pre-determined diameters at right angles was measured on the second and fourth days after inoculation. The mean growth rate (mm./day) over this arbitrary period was used to measure fungistatic activity, and was subjected to statistical analysis. The approximate concentration required to reduce mycelial growth by 50% ("ED₅₀") was estimated graphically by plotting the growth response (expressed as probits) against the logarithm of a series of dosages.

(b) *Spore germination test.*

The method used was based on the test-tube dilution technique of the American Phytopathological Society (12). Briefly, 0.2 ml. of spore suspension (250,000/ml.) of *V. inaequalis* was added to 0.8 ml. of each of four concentrations of the fungicides tested; this brought the final concentrations of active material to 10, 1, 0.1, 0.01 p.p.m. respectively, and that of spores to 50,000/ml. After thorough agitation, two drops of these mixtures were pipetted out on glass slides previously coated with cellulose acetate. The slides were incubated in a moist chamber at 18°C. for 20-24 hours; germination of 100 spores per treatment was then recorded. For ease of dispersal in water, fungicides were formulated as wettable powders when not available in this form.

Results.(a) *Mycelial growth tests.*

Table I shows the approximate ED_{50} values for each compound against the mycelial growth of *S. laxa*.

TABLE I.
APPROXIMATE ED_{50} VALUES OF FUNGICIDES
AGAINST MYCELIAL GROWTH OF *S. LAXA*.

Compound	ED_{50} value (p.p.m.)
Griseofulvin	0.1
Nystatin	1.5
Acti-triin	0.7
<i>o</i> -Hydroxy-diphenyl	0.8
Bisphenol "NF-14"	3.6
Bisphenol "G-4"	2.2
Bisphenol "Cr.305"	1.2
"Quinaldinium DAQC"	28.2*
"Isoquinaldinium HQC"	>10.0
Triazine "B.622"	19.9
<i>n</i> -Dodecyl-guanidine acetate	0.9

* By extrapolation.

(b) *Spore germination tests.*

Table II shows the percentage inhibition of spore germination (calculated on the basis of the control germination figure) for each of the fungicides at four concentrations. Nystatin and acti-triin were not available in sufficient quantity for inclusion in this test.

TABLE II.
CORRECTED PERCENTAGE INHIBITION OF SPORE GERMINATION OF *V. INÆQUALIS*.

Compound	Final concentration (p.p.m.)			
	10	1	0.1	0.01
Griseofulvin	8.0	0.0	0.0	1.4
<i>o</i> -Hydroxy-diphenyl	84.6	75.8	8.9	3.3
Bisphenol "NF-14"	2.2	4.4	0.0	0.0
Bisphenol "G-4"	11.0	4.4	0.0	0.0
Bisphenol "Cr.305"	11.0	0.0	4.4	1.1
"Quinaldinium DAQC"	3.3	3.3	2.2	0.0
"Isoquinaldinium HQC"	84.8	2.2	0.0	0.0
Triazine "B.622"	92.3	87.9	26.4	33.0
<i>n</i> -Dodecyl-guanidine	78.7	41.3	20.0	10.7
Captan	93.5	23.9	3.6	—

(c) *Field tests.*

During 1956 and 1957, griseofulvin, *o*-hydroxy-diphenyl, triazine "B.622" and captan were included in pilot-scale scab trials on the variety Worcester Pearmain. The disease did not develop, even on control trees, and no scab assessment could therefore be carried out. In these, and in other preliminary trials on phytotoxicity, no damage to apple foliage and fruit followed the application of these materials:—griseofulvin, 0.1%; nystatin, 0.2%; phenolics "Cr.305", "G-4" and "NF-14", each at 0.2%; triazine "B.622", 0.1%. Slight scorching followed the use of *o*-hydroxy-diphenyl (0.1%). All concentrations are quoted in terms of active material.

Discussion.

Of the compounds tested, *n*-dodecyl-guanidine acetate and *o*-hydroxy-diphenyl showed high fungistatic activity against both *V. inaequalis* and *S. laxa*. Whilst it has not been possible to test the former for phytotoxicity, there is some evidence to suggest that *o*-hydroxy-diphenyl may cause scorch to apple foliage at effective concentrations.

The triazine "B.622" inhibited germination of *V. inaequalis*, even at very low concentrations; like captan (13) the compound was much less effective against mycelial growth. On the other hand the bisphenolic compounds and griseofulvin showed moderate to high activity against the mycelium of *S. laxa* but were ineffective in the spore germination test, even at 10 p.p.m. The quinaldinium and isoquinaldinium compounds showed little promise in either test. The antibiotics nystatin and acti-triin were active against mycelial growth of *S. laxa* but no data are available for *V. inaequalis*.

On the basis of the results above, *n*-dodecyl-guanidine acetate, *o*-hydroxy-diphenyl and the triazine "B.622" appear to warrant trial on an orchard scale.

Summary.

- (1) Eleven compounds were tested for their ability to inhibit spore germination of *Venturia inaequalis* and mycelial growth of *Sclerotinia laxa*.
- (2) On the basis of these preliminary tests, *n*-dodecyl-guanidine acetate, 2:4-dichloro-6-(*o*-chloroanilino)-s-triazine and *o*-hydroxy-diphenyl appear to warrant field testing; the latter compound, however, was liable to cause phytotoxicity at 0.1%.

Acknowledgments.

The authors wish to thank Miss M. Waller for valuable assistance in laboratory tests, and the following for kindly supplying samples as indicated:—Dr. H. O. J. Collier, Allen and Hanburys Ltd.—quinaldinium "HQC" and isoquinaldinium "DAQC"; Dr. J. G. Horsfall, Connecticut Agricultural Experiment Station—bisphenol "Cr.305"; Dr. H. G. Shirk, Prevention of Deterioration Center, Washington, D.C.—bisphenols "G-4" and "NF-14"; Cyanamid of Great Britain Ltd.—*n*-dodecyl-guanidine acetate; Glaxo Laboratories Ltd.—griseofulvin; Nuodex Ltd.—triazine derivative.

REFERENCES.

- (1) BRIAN, P. W. (1949). Studies on the biological activity of griseofulvin. *Ann. Bot., Lond.*, **13**, 59.
- (2) RHODES, A., CROSSE, R., McWILLIAM, R., TOOTILL, J. P. R. and DUNN, A. T. (1957). Small-plot trials of griseofulvin as a fungicide. *Ann. appl. Biol.*, **45**, 215.
- (3) BROWN, R. and HAZEN, E. (1957). Present knowledge of nystatin, an antifungal antibiotic. *Trans. N.Y. Acad. Sci.*, Ser. 2, **19**, 447.
- (4) DiMARCO, G. R. and DAVIS, B. H. (1957). Prevention of decay of peaches with post-harvest treatments. *Phytopathology*, **47**, 224. (Abs.).
- (5) COLES, G. V., MARTIN, J. T. and BYRDE, R. J. W. (1957). The fungistatic properties of coal tar constituents. *Ann. Rep. Long Ashton Res. Sta. for 1956*, 101.
- (6) COREY, R. R. and SHIRK, H. G. (1955). The influence of chemical structure on fungal activity IV. The effect of bisphenolic-type compounds. *Arch. Biochem. Biophys.*, **56**, 196.
- (7) HORSFALL, J. G. (1956). *Principles of fungicidal action*, p.41. Waltham, Mass.: Chronica Botanica.
- (8) BABBS, M., COLLIER, H. O. J., AUSTIN, W. C., POTTER, M. D. and TAYLOR, E. P. (1956). Salts of decamethylene-bis-4-amino quinaldinium ("dequadin"), a new antimicrobial agent. *J. Pharmacy & Pharmacol.*, **8**, 110.
- (9) COLLIER, H. O. J., POTTER, M. D. and TAYLOR, E. P. (1955). Antifungal activities of bis *iso* quinolinium and bis quinolinium salts. *Brit. J. Pharmacol.* **10**, 343.
- (10) SCHULDT, P. H. and WOLF, C. N. (1956). Fungitoxicity of substituted *s*-triazines. *Contrib. Boyce Thompson Inst.*, **18**, 377.
- (11) KIRKHAM, D. S. (1956). A culture technique for *Venturia* spp. and a turbidimetric method for the estimation of comparative sporulation. *Nature*, **178**, 550.
- (12) AMERICAN PHYTOPATHOLOGICAL SOCIETY. Committee on standardization of fungicidal tests. (1947). Test-tube dilution technique for use with the slide-germination method of evaluating protectant fungicides. *Phytopathology*, **37**, 354.
- (13) BYRDE, R. J. W. (1952). Experiments on the control of brown rot of apples and plums: I. Laboratory tests. *J. hort. Sci.*, **27**, 130.

SPRAYING EXPERIMENTS AGAINST APPLE SCAB AT LONG ASHTON, 1957.

By R. J. W. BYRDE, G. M. CLARKE and C. W. HARPER.

The three previous reports in this series (1, 2, 3) described an experiment to compare captan and lime sulphur used as post-blossom fungicides on Cox's Orange Pippin apples which had received lime sulphur as the pre-blossom fungicide. The substitution of captan for lime sulphur post-blossom was followed by an increased incidence of apple mildew (caused by *Podosphaera leucotricha* (Ell. and Everh.) Salm.) and an increase in crop weight, at least on Type II rootstock. There was also evidence that in seasons when fruit russetting developed, particularly on Type IX rootstock, its incidence was less on captan-treated plots.

In 1957, a uniform captan treatment was applied both pre-blossom and post-blossom to the whole experimental area, with the object of obtaining information on any "residual" effects of the previous year's treatments. As in previous seasons, scab, caused by *Venturia inaequalis* (Cooke) Wint., was at a very low level. This paper presents the results obtained in 1957 and also summarizes the experiment as a whole: a more detailed account is being published elsewhere (4).

Experimental.

Fungicide. Captan (N-trichloromethylthio-tetrahydrophthalimide) was applied to the entire experimental area at the rate of $1\frac{1}{2}$ lb. per 100 gal. of a commercial 50% wettable powder on seven occasions during 1957. Since there were thus no differential treatments in 1957, any "treatment" difference could be ascribed to the residual effect of the previous year's treatments.

Layout. The layout of this experimental area was described in (1); the planting systems referred to as IIA, IIB, IXB respectively are M.II rootstock without "fillers", M.II rootstock with "fillers", and M.IX rootstock used as "fillers".

Methods of assessment. These were identical with the methods used in 1955 (2), except that in addition primary mildew was assessed on vegetative shoots of the previous year's growth, by a method similar to that used for blossom trusses. Crop weight was recorded to the nearest lb.

Notes on weather. The early months of the 1957 growing season were dry, with an exceptionally sunny June; subsequent months were wet. The rainfall figures (in.) for each month are shown below with average figures (1914-53) in brackets.

April, 0.14 (2.33)	July, 4.47 (3.16)
May, 1.94 (2.59)	August, 3.15 (3.65)
June, 1.79 (2.11)	September, 4.57 (3.15)

Total 16.06 (16.99). Deficit 5.5%.

Results.

On foliage and blossom trusses.

Apple mildew was assessed on blossom trusses on April 25th, 1957. 90 trusses were examined per treatment in each planting system. The numbers of infected trusses on plots receiving lime sulphur and captan respectively in 1956 were:—System IIA : 0, 0; System IIB : 1, 1; System IXB : 0, 0.

Mildew which had overwintered as bud infections on vegetative shoots was also assessed in 1957, on May 30th. The percentages of shoots bearing infected leaves on plots which had received lime sulphur and captan respectively in 1956 were:—System IIA : 7.3, 19.4; System IIB : 4.4, 14.6; System IXB : 4.9, 22.7. These treatment residuals differed significantly (at the 1% level) in planting systems IIA and IXB.

An assessment of "secondary" apple mildew infection on shoots of the current season's growth was carried out on August 29th, 1957. The following percentages of shoots showing any leaf infection were recorded for plots which had received lime sulphur and captan treatments respectively in 1956:—System IIA : 74.7, 88.3; System IIB : 68.3, 85.0; System IXB : 66.0, 85.7. These treatment residuals did not differ significantly.

On fruit.

The fruit of the variety Cox's Orange Pippin was picked on September 12th-13th (Type IX) or September 23rd (Type II). The total fruit from each recorded plot was again bulked in three batches corresponding to the three planting systems, and random samples of about sixty fruits were taken from

orchard boxes by the method of Pearce (5) and scab and fruit russet assessed at once on these samples. The mean percentage of fruit area scabbed, either for lime sulphur or captan treatments in 1956, was 0.00 in all three planting systems.

Fruit russet was observed on only 6 fruits out of over 1,000 examined.

Crop weight data, expressed as mean weight (lb.) per tree, excluding replants, for plots which had received lime sulphur and captan treatments respectively in 1956, were as follows: System IIA: 136.0, 162.8; System IIB: 149.0, 156.3; System IXB: 77.2, 61.3. The treatment difference was significant (at the 5% level) on planting system IIA.

Commercial grading was carried out on the bulked crop from October 1st-10th. Data for fruit size and colour are summarized in Table I, averaged for all blocks within each planting system. No difference was apparent between the percentages of fruit of "Fancy" grade on the plots which had received either fungicide in 1956; the fruit of "Fancy" grade below $2\frac{1}{4}$ in. in diameter was a very small part of total "Fancy", and the slight indication that captan may lead to a lower percentage of small fruit was therefore unimportant.

TABLE I.
GRADING DATA: FRUIT SIZE AND COLOUR.
Mean percentage field crop in each category, October, 1957.

Planting system	Post-blossom fungicide in 1956	Total fruit of at least "Fancy" grade	"Fancy" fruit graded for size		Fruit of "Fancy" size but below standard for colour	3rd grade (small, green, blemish, culls)	Loss in store
			> $2\frac{1}{4}$ in. diam.	< $2\frac{1}{4}$ in. diam.			
IIA	Lime sulphur	59.2	52.9	6.3	8.6	27.7	4.5
	Captan	58.5	55.8	2.7	12.9	24.6	4.0
IIB	Lime sulphur	61.2	48.4	12.8	7.6	27.2	4.0
	Captan	60.0	50.7	9.3	9.5	26.9	3.6
IXB	Lime sulphur	51.0	39.3	11.7	12.8	30.9	5.3
	Captan	50.2	44.7	5.5	14.7	29.7	5.4

In addition to a small proportion of fruits infected in the field by the brown rot fungus, *Sclerotinia fructigena*, Aderh. & Ruhl., some apples became infected during September by *Rhizopus* sp., which normally causes only storage rot (6).

Discussion.

1957 results.

Although no differential sprays were applied during 1957, the disease and crop data obtained have been useful for estimating residual effects of the 1956 treatments. There was a significant residual effect in favour of captan on crop weight data for planting system IIA, whilst a similar effect on planting system IIB failed to attain statistical significance. On planting system IXB there was no significant treatment effect, although the lime sulphur figure was somewhat higher.

There was a marked difference in the level of "primary" mildew infection on 1956 shoots, which was higher on plots receiving captan in 1956. Comparison of these data with those for blossom truss infection suggests that truss infection was of little importance in this trial as an overwintering source of inoculum (7) and helps to explain apparent anomalies in earlier years between the level of blossom infection and subsequent "secondary" infections of shoots. In 1957 the level of secondary infection was higher on plots receiving captan in 1956, but not by an amount sufficient to attain statistical significance. Scab and russet were virtually absent in 1957.

Summary of full experiment.

A full account of this experiment, which was started in 1954, is being published elsewhere (4), but it may be useful to present a brief summary of the main findings and conclusions here.

Apple scab was at a very low level throughout the experiment. Apple mildew was more severe on plots receiving captan as post-blossom fungicide, with some indications of a "residual" effect from the previous season's treatments. The use of captan on Type II rootstock was followed by a mean increase in crop weight over the three years of 25 lb. per tree per year, representing a 42% increase, and there was also evidence of some "residual" effect from one season to the next, also in favour of captan. On Type IX rootstock, however, treatments had little effect on crop weight, but in the two years when serious fruit russet developed on this variety it was much less widespread on captan-treated plots.

In practice, it seems that where a specific mildew fungicide is not used, the commercial use of captan may be governed largely by the relative magnitude, on an economic basis, of its effects on crop and mildew. Under the conditions of this particular experiment, the balance favoured captan, but this result is not necessarily valid for other localities.

Summary.

- (1) A uniform spray treatment of captan (0.075%) was applied in 1957 to trees used in the three previous seasons for a comparison of lime sulphur and captan as post-blossom fungicides.
- (2) The incidence of apple scab, caused by *Venturia inaequalis*, and of disfiguring fruit russet was virtually nil.
- (3) The level of "primary" shoot infections of apple mildew, caused by *Podosphaera leucotricha*, was significantly greater on plots receiving captan in 1956. The level of "secondary" infections was also higher, though the treatment difference was not statistically significant.
- (4) On Type II rootstock there was a greater crop on plots that had received captan in 1956.
- (5) The results of the whole experiment (1954-57) are summarized.

Acknowledgments.

The authors wish to thank Mr. E. W. Hobbis and Mr. E. Catlow for placing the trees at their disposal and supplying detailed crop and grading data, Mr. R. W. Marsh for his continued interest, Miss M. E. Holgate for carrying out statistical analyses, and Misses M. Marlow, M. Waller and N. Waugh for assistance in recording. Mr. R. T. Burchill kindly carried out the mildew recording. Meteorological data were kindly supplied by Mr. G. E. Clothier from the Station records.

REFERENCES.

- (1) BYRDE, R. J. W., CLARKE, G. M. and HARPER, C. W. (1955). Spraying experiments against apple scab at Long Ashton, 1954. *Ann. Rep. Long Ashton Res. Sta. for 1954*, 147.
- (2) BYRDE, R. J. W., CLARKE, G. M. and HARPER, C. W. (1956). Spraying experiments against apple scab at Long Ashton, 1955. *Ann. Rep. Long Ashton Res. Sta. for 1955*, 140.
- (3) BYRDE, R. J. W., CLARKE, G. M. and HARPER, C. W. (1957). Spraying experiments against apple scab at Long Ashton, 1956. *Ann. Rep. Long Ashton Res. Sta. for 1956*, 103.
- (4) BYRDE, R. J. W., CLARKE, G. M. and HARPER, C. W. (1958). A three-year comparison of captan and lime sulphur as post-blossom fungicides on Cox's Orange Pippin apples. *J. hort. Sci.* **33**, (in Press).
- (5) PEARCE, S. C. (1947). The measurement of fruit crops by sampling. *Ann. Rep. E. Malling Res. Sta. for 1946*, 77.
- (6) WORMALD, H. (1955). *Diseases of fruit and hops* (3rd Ed.) 325 pp. London: Crosby Lockwood.
- (7) BURCHILL, R. T. (1958). Observation on the mode of perennation of apple mildew. *Ann. Rep. Long Ashton Res. Sta. for 1957*, 114.

A PRELIMINARY COMPARISON OF THE TEMPERATURE-GERMINATION RELATIONSHIPS OF ASCOSPORES AND OF CONIDIA OF THE APPLE AND PEAR SCAB FUNGI (*VENTURIA INÆQUALIS* AND *V. PIRINA*).

By D. WHEATLEY.*

In the apple and pear scab diseases, a critical factor in the establishment of infection is the time needed for the germination of the fungus spores. These spores require a period of wetting before they will germinate and the duration of this period is dependent on temperature. This relationship is the basis of the well-known "Mills Scale" which gives the minimum periods of leaf wetness required at different temperatures to permit scab infection of apple leaves. This scale applies only to the ascospores of the apple scab fungus, although Mills states that "in the case of conidia of *Venturia inaequalis* the time the leaves must remain wet is approximately one-third less than that given for ascospores". No corresponding data have been given for either the ascospores or the conidia of pear scab.

In the work described below the aim was to determine, at different temperatures, the percentage germination and rate of germ-tube growth for both ascospores and conidia of the apple scab fungus and to compare the results from the apple scab conidia with those using the conidia of pear scab. As it was known that germination data for these fungi obtained on glass slides differed from those recorded on leaves, the germination experiments were all carried out on living leaves of the appropriate host plant.

The investigation was restricted to the months of May and June 1957, and the results obtained are presented as preliminary records, from which only tentative conclusions can be drawn.

* Present address: College of Technology, Kumasi, Ghana. The work reported in this paper was done at the Long Ashton Research Station in partial fulfilment of the requirements of the University of Bristol Diploma in Plant Pathology and Protection.

Experimental.

Collection and preparation of spore inocula. Conidia of *V. inaequalis* were freshly obtained as required from young, naturally-occurring infections on leaves of unsprayed trees of Cox's Orange Pippin at Long Ashton. Conidia of *V. pirina* were taken from fruitlets of Williams' Bon Chrétien pear, as no scab lesions were available on pear leaves at Long Ashton in the early summer of 1957. Spore suspensions were produced by agitating a portion of the infected material in about 2 ml. of tap-water and then adjusting to the required concentration of 50,000 spores per ml. as determined by a haemocytometer.

In the absence of perithecia-bearing overwintered apple leaves at Long Ashton, sources of ascospore material (overwintered leaves of Bramley's Seedling) were kindly provided by Dr. E. L. Hirst of Rothamsted Experimental Station and Dr. M. H. Moore of East Malling Research Station. Areas with a high concentration of perithecia were cut from these leaves, soaked 5 min. in water and then transferred, with the ventral surface downwards, on to a wire grid supported in a petri dish. A moistened filter paper was laid over the leaves and the lid replaced. The ascospores were subsequently ejected from the perithecia on to the base of the dish, from which they were brushed off with a camel-hair brush immediately after discharge and suspended in water to give the standard concentration of 50,000 spores per ml.

Application of spores to leaves. Freshly-detached young leaves were held in place on a glass slide by two elastic bands and the slide was placed on a bent glass rod in a moist chamber formed by an inverted closed petri dish with water in the lid. Leaves of Cox's O.P. were used for experiments with *V. inaequalis*; those of Williams' B.C. for experiments with *V. pirina*. A 0.02 ml. drop of the appropriate spore suspension was applied to the upper leaf surface at its broadest part midway between the midrib and the leaf margin. In experiments comparing ascospores with conidia of *V. inaequalis* each leaf carried the two types of spore in separate drops. Where comparisons were made between conidia of *V. inaequalis* and those of *V. pirina* each petri dish contained both an apple and a pear leaf.

Incubation. The spores were incubated by placing the petri dishes in incubators at the following temperatures ($\pm 2^\circ\text{C}.$): 10° , 15° , 20° , 25° and $30^\circ\text{C}.$

Recording. After the required time intervals, the leaves were removed from the petri dishes and some of the water in the spore-suspension drop was carefully withdrawn, using the edge of a filter paper. The leaf was subsequently left exposed to the air for about 5 min. to allow the drop to dry completely. Using a modification of the method described by Bennett and Furrmidge (1), the inoculated area of the leaf surface was then painted with collodion film which, after drying, was stripped off, taking with it, without distortion, all the spores and germ-tubes on the leaf surface. The transparent film was mounted on a glass slide in lacto-phenol or polyvinyl acetate tinged with cotton blue. A few minutes' gentle warming gave adequate staining of the spores and germ tubes.

For each recording, 50 spores per film were taken at random and the number not germinated and the length of germ-tube from each germinated spore were noted. Where two germ-tubes were present on one spore, or where branching occurred, the total germ-tube length was recorded. The sum of the lengths (in microns) of the germ-tubes produced by the 50 spores was divided by 50 to give a mean germ-tube length ($\bar{l}$) per spore. The mean germ-tube

length per germinated spore was also calculated and is represented by $\bar{l}$ (g) in Tables 1 to 4. These tables also show the percentage spore germination for each batch.

Results.

Comparisons between ascospores and conidia of V. inaequalis.

Table I gives the results of a comparison made on 16-17 May of the germination on leaves of Cox's O.P. apple of a sample of ascospores and one of conidia of *V. inaequalis*. The comparisons were made at four temperatures and for three periods of time, the ascospores and conidia for each time-temperature comparison being on the same leaf. The table gives percentage germinations and mean germ-tube lengths of the germinated spores.

TABLE I.

COMPARISON BETWEEN GERMINATIONS OF ASCOSPORES AND CONIDIA OF *V. INAEQUALIS*.

Temp.	Value	Period					
		17 hr.		22 hr.		41 hr.	
		Ascospores	Conidia	Ascospores	Conidia	Ascospores	Conidia
10°C.	% germ.	76%	90%	78%	88%	84%	84%
	$\bar{l}$ (g) (in μ)	16.7	26.8	25.7	34.8	55.5	44.7
15°C.	% germ.	80%	90%	88%	94%	86%	84%
	$\bar{l}$ (g)	34.8	44.4	44.6	35.5	27.5	32.9
20°C.	% germ.	80%	88%	76%	92%	76%	92%
	$\bar{l}$ (g)	24.9	39.2	42.6	54.9	40.8	42.2
25°C.	% germ.	58%	88%	92%	80%	88%	94%
	$\bar{l}$ (g)	18.8	43.6	21.1	23.9	36.3	62.5

It will be noted that, in the twelve comparisons shown in this table, the germination percentage for the sample of conidia is higher than that for the sample of ascospores in nine instances, equal in one, and lower in two. Similarly in germ-tube growth the conidia show the higher figure in ten of the twelve comparisons. Figs. 1 and 2 illustrate the germination comparisons for all the periods recorded at 10° and 20°C. and the germ-tube lengths after 17 hr. for the four temperatures.

The trial was repeated on 3-4 June, employing six temperatures and six time periods (8, 10, 12, 15, 18 and 24 hr). This experiment showed an even greater difference in favour of the conidia : the results for 20°C. for each period are shown in Fig. 3. At this date, however, it is possible that the viability of the ascospores had declined, and therefore less weight can be given to these June results.

Comparisons between V. inaequalis and V. pirina.

The comparisons between the apple and the pear scab fungi were made only with conidia, as no ascospore material of *V. pirina* was available. Table II gives the results of an experiment made at five temperatures and for five periods of incubation.

%
germination

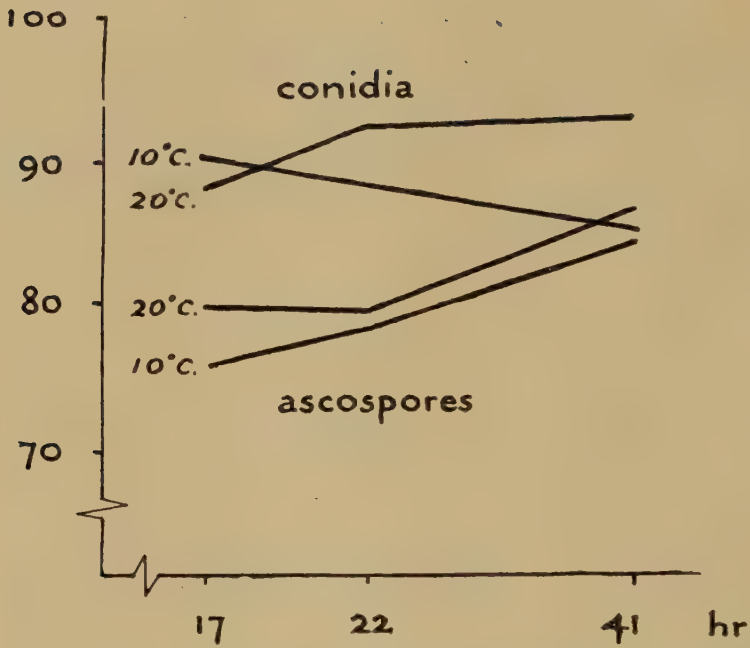


Fig. 1. Percentage germination of ascospores and conidia of *V. inaequalis*.

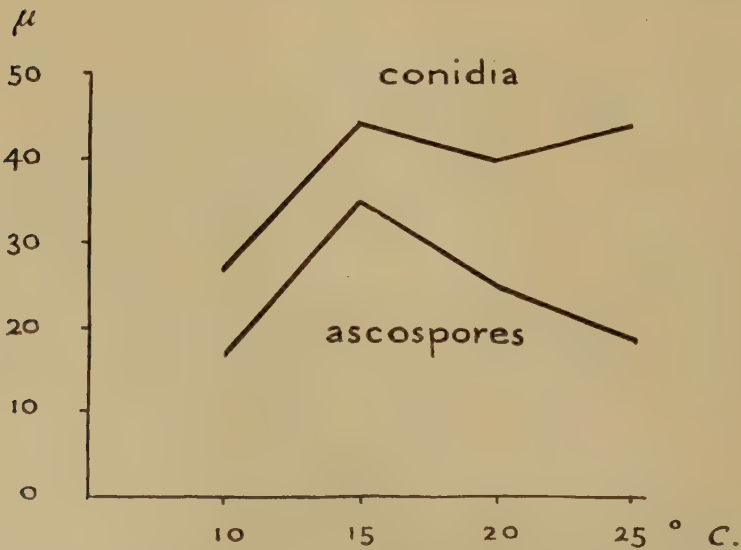


Fig. 2. Germ-tube lengths of germinated ascospores and conidia of *V. inaequalis* after 17 hr. at 10°, 15°, 20° and 25°C.

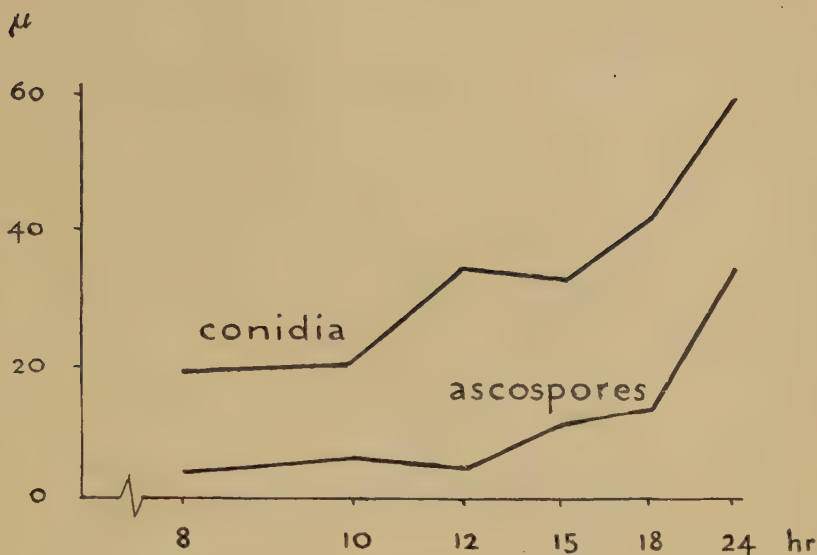


Fig. 3. Germ-tube lengths of germinated ascospores and conidia of *V. inaequalis* after 8, 10, 12, 15, 18 and 24 hr. at 20°C.

Table II does not show consistent differences in percentage germination between conidia of *V. inaequalis* and those of *V. pirina*, but the differences in mean germ-tube length are striking. In 24 of the 25 comparisons the germ-tubes of the pear scab conidia have outgrown those of the conidia of apple scab. This is illustrated in Fig. 4, comparing the lengths of germ-tubes after 40 hr. at the five recorded temperatures, and in Fig. 5, showing comparisons at 20° and at 30°C. for each of the five incubation periods.

Fig. 5 shows that at both temperatures the growth of the pear scab conidia consistently exceeded that of the conidia of apple scab. The difference is specially noticeable in the records taken after 20, 24 and 40 hr. at 30°C., suggesting that this relatively high temperature checks the growth of the pear scab fungus less than that of apple scab.

Discussion.

The records obtained in this preliminary investigation are too scanty to be suitable for statistical analysis: a number of repetitions of such spore germination trials would be required to provide sufficient data to give a basis for firm conclusions. Such replication of experiments is particularly necessary in dealing with the apple and pear scab fungi, which are known to comprise a number of strains showing different infectivities on specific varieties of the host.

Therefore, in the comparison recorded in Table I between a sample of apple scab ascospores and one of conidia, the criticism could be made that both were sown on leaves of Cox, the source variety for the conidia but not for the ascospores. It is possible that the ascospores, being derived from Bramley leaves, would have germinated better on this variety. Further, although the ascospores were freshly discharged when used, it is not certain

TABLE II.
COMPARISON BETWEEN GERMINATION OF CONIDIA OF *V. inaequalis* AND THOSE OF *V. pirina*.

Temp.	Value	Period							
		12 hr.		17 hr.		20 hr.		24 hr.	
		<i>V. inaeq.</i>	<i>V. pirina</i>	<i>V. inaeq.</i>	<i>V. pirina</i>	<i>V. inaeq.</i>	<i>V. pirina</i>	<i>V. inaeq.</i>	<i>V. pirina</i>
10°C	$\left\{ \begin{array}{l} \% \text{ germ.} \\ 1(g), \text{ in } \mu \end{array} \right\}$	70% 24.7	76% 23.4	94% 32.5	74% 34.9	84% 15.5	86% 37.2	98% 60.4	100% 63.1
15°C	$\left\{ \begin{array}{l} \% \text{ germ.} \\ 1(g) \end{array} \right\}$	76% 19.8	74% 23.7	94% 28.9	86% 35.8	88% 29.9	92% 35.9	88% 24.7	96% 63.2
20°C	$\left\{ \begin{array}{l} \% \text{ germ.} \\ 1(g) \end{array} \right\}$	98% 33.5	92% 57.7	98% 55.6	82% 72.8	96% 51.1	90% 92.0	94% 44.0	98% 93.6
25°C	$\left\{ \begin{array}{l} \% \text{ germ.} \\ 1(g) \end{array} \right\}$	94% 39.9	98% 66.7	86% 53.5	94% 62.6	90% 53.3	98% 73.0	96% 42.8	96% 91.3
30°C	$\left\{ \begin{array}{l} \% \text{ germ.} \\ 1(g) \end{array} \right\}$	62% 7.1	52% 15.4	66% 13.0	62% 20.5	84% 16.3	76% 52.1	74% 13.0	70% 81.4
								76% 16.7	72% 85.8

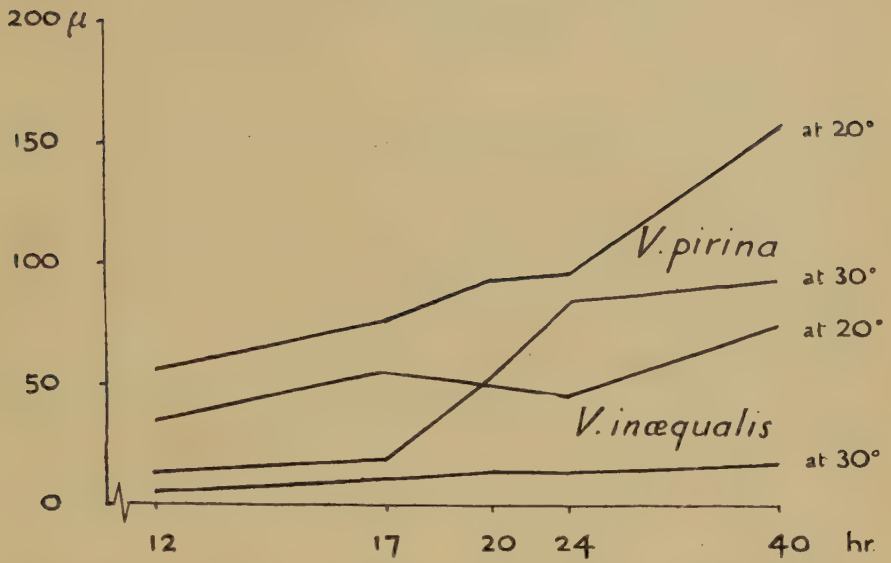


Fig. 4. Germ-tube lengths of germinated conidia of *V. pirina* and *V. inaequalis* after 40 hr.

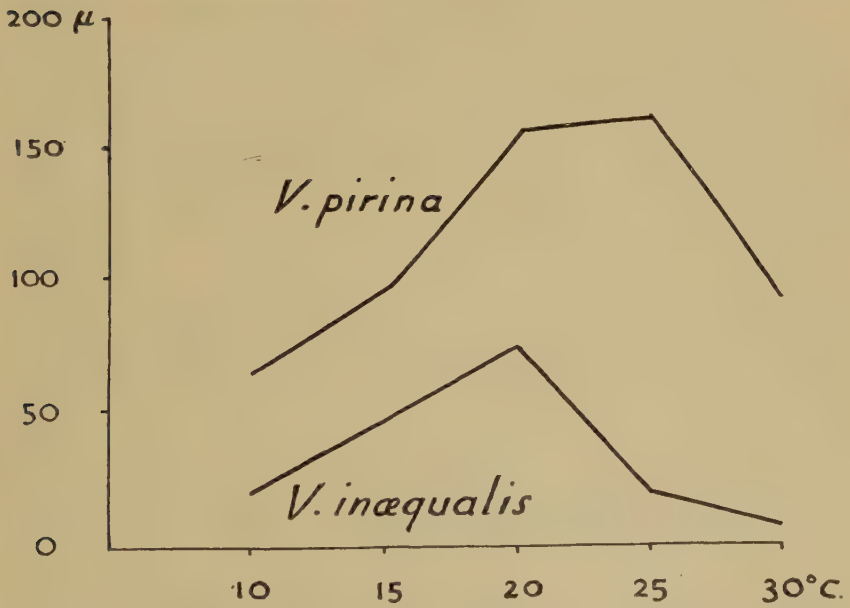


Fig. 5. Germ-tube lengths of germinated conidia of *V. pirina* and *V. inaequalis* at 20° and at 30°C.

that they were at the peak of their viability : it is conceivable that if tested in April they might have germinated better than in May. The subsequent experiment made on June 3rd strongly indicated that ascospore viability was waning by that date. The conidia, on the other hand, were freshly derived from young, vigorous infections.

Consequently, although the trend shown in Table I is towards a higher percentage germination and a more rapid germ-tube growth for the conidia than for the ascospores, this result may have been biased by some aspects of the technique employed.

The experiment recorded in Table II, in which conidia of apple scab were compared with conidia of pear scab, is less open to criticism, since both collections of spores were freshly obtained from young infections and sown on leaves of the source variety. This comparison clearly showed a trend towards a more rapid rate of growth of the pear scab conidia at all the temperatures employed. It does not necessarily follow that leaf penetration and the establishment of infection would occur more readily in the pear than in the apple, but it appears probable that the quicker growth of the pear scab fungus would help to confer an advantage in the establishment of infection. This may account for the observation frequently made in the field that the spread of pear scab can occur during periods of leaf wetting that are too brief to permit new infections by the apple scab fungus.

Summary.

A method of making spore germination tests on leaf surfaces is described.

In a preliminary spore germination comparison, made on leaves of Cox's Orange Pippin in May, apple scab conidia collected from leaves of Cox showed generally higher percentage germination and more rapid growth than apple scab ascospores derived from overwintered leaves of Bramley's Seedling.

In a similar comparison between conidia of the pear scab fungus and conidia of apple scab, the pear scab conidia sown on leaves of Williams outgrew apple scab conidia sown on leaves of Cox.

Acknowledgments.

Grateful acknowledgment is made to Dr. C. G. L. Furmidge for his help in developing the method of transferring the germinated spores in transparent films, and to Mr. R. W. Marsh, under whose direction this investigation was carried out.

REFERENCE.

- (1) BENNETT, S. H. and FURMIDGE, C. G. L. (1956). Spray application problems : XXIV. The study of plant surfaces and spray deposits by means of transparent impressions. *Ann. Rep. Long Ashton Res. Sta. for 1955*, 121.

THE REDUCTION OF ORCHARD SOURCES OF *GLOEOSPORIUM* DISEASE.

By R. O. SHARPLES.

In recent years severe losses of stored apples have been caused by bitter rot, due to two species of *Gloeosporium*: *G. perennans* Zeller & Childs and *G. album* Osterwalder. The infection of the fruits is initiated during their development on the tree and is brought about by conidia discharged from *Gloeosporium* infections on apple shoots and branches. These wood infections form the principal subject of this report, which describes the methods by which *Gloeosporium* spp. overwinter in the orchard.

In addition an account is given of a series of inoculation experiments made to examine the possibilities of avoiding infections of pruning wounds. Results are also given of pilot-scale trials of eradicant fungicides, aimed at suppressing sporulation of *G. perennans* on existing wood infections during the period of fruit development.

Orchard Infection.

Sources of conidial infection.

The source of conidial infection in the orchard may be cankers and extensive dieback lesions, resulting from the invasion of shoot injuries by *Gloeosporium*. These shoot infections produce sporing pustules (acervuli) which, during periods of rain, discharge conidia which may be washed or carried to the lenticels of the fruit where they can initiate latent infections. Until recently these branch canker and dieback infections had been assumed to provide the principal source of inoculum for fruit infection, but Guthrie (1) has shown that the inoculum in some plantations is adequately accounted for by saprophytic infections of both *G. perennans* and *G. album* on dead stubs, snags and fruiting spurs (collectively termed "stubs") and mummified fruitlets. At Long Ashton, *Gloeosporium* rots on stored Allington fruit have been shown to originate from similar types of infection on short lengths of dead wood; for example, in one orchard, from which 8.4% fruit rot was subsequently recorded in store, 10.4% of the dead stubs were found to be harbouring *G. perennans* while a further 4.2% were infected with *G. album*. In a Hampshire orchard the main source of *Gloeosporium* infection in the winter of 1957-8 was shown to be mummified fruitlets still attached to the trees. The association of *G. album* with stub infections and mummified fruitlets is of particular interest in view of the very weak parasitism of this species on Cox and Allington wood (2).

Experiments carried out at Long Ashton in 1955-7 demonstrated that, under laboratory conditions, saprophytic infections of *G. album* and *G. perennans* may be established also on fallen Cox and Allington leaves, where they may produce acervuli after 2-4 weeks in moist chambers. A limited number of natural infections also occurred on these experimental leaves, while Edney (3) has reported natural *Gloeosporium* infections on petioles obtained from orchards in south-east England. On the other hand, in field experiments at Long Ashton, in which fallen leaves of the two varieties were artificially infected with *Gloeosporium* in the autumn, no fructifications were

produced after December of the same year. There is no evidence from this work that infected leaves play a significant part in the over-wintering of the disease in West Country orchards.

The perfect stage of G. perennans.

In general, orchard infections with *G. perennans* and *G. album* are brought about by the conidial stages of these fungi. Recently, however, the perfect stages have also been recorded in this country by Guthrie (1).

The perfect stage of *G. perennans* was first described in 1939 by Kienholz (4) in Oregon under the name *Neofabraea perennans* (Zeller and Childs) Kienholz. In October 1956 apothecia were recorded on natural and artificially-induced shoot infections of *G. perennans* in several localities in Holland by Bolay (5) who preferred the synonymous name of *Pezicula malicorticis* (Jackson) Nannfeldt for this species.

In April 1957 apothecia morphologically similar to those described by Kienholz were produced on natural shoot infections collected from Allington trees at Long Ashton and incubated in moist chambers at room temperature for 2 weeks. In October 1957 large numbers of apothecia were produced on eighteen cut shoots bearing cankers that had been artificially induced by pure-culture inoculations with mycelium or conidial suspensions of *G. perennans* on both Cox and Allington (Plate V, Fig. 3) in the autumn of 1955 and 1956. The shoots had been detached in December 1956 and stored out-of-doors for 9 months on grass or sand in wire cages.

Details of the structure of the fructifications produced at Long Ashton have been given by Sharples (6). The apothecia become convex at maturity (Plate V, Fig. 4) measuring 0.5-1.0 mm. in diameter and 0.25-0.4 mm. in height. They have a waxy appearance and are dark brown, becoming lighter in colour when moist. During moist weather, ascospores are forcibly ejected from the apothecia and dispersed in air currents. The cultural characteristics of ascospore isolations and pathogenicity tests confirmed that the ascigerous material was of the same species as the conidial stage, *Gloeosporium perennans*.

Factors affecting the susceptibility of pruning cuts to infection by *G. perennans*.

Corke (2) has shown that the frequency with which pruning wounds, made by the excision of a lateral shoot, develop into extensive lesions after inoculation with spores of *G. perennans* is inversely proportional to the seasonal level of host activity. Confirmation of the overall importance of the degree of host resistance in the development of shoot infections has been obtained from studies of the anatomy of lesions arising from pin-stab and pruning-cut wounds (6). In the present investigation the influence of several additional factors on the susceptibility of pruning wounds of different types was examined.

Three different types of wound were distinguished for the purposes of this work:—

- (i) Laterals : wounds made by the removal of a lateral shoot.
- (ii) Terminals : wounds made by the removal of the end of a shoot by a cut made just above a bud.
- (iii) Snags : wounds made by cutting back just below a bud.

Freshly-made wounds were inoculated by placing a drop of spore suspension in sterile water, at an approximate concentration of 50,000 spores per ml., on the exposed surface. After the drop had disappeared the wound was bound with self-adhesive crepe rubber. The viability of the spores was checked by parallel slide germination tests.

Position of pruning wound on 2-year-old wood.

The seasonal variations in susceptibility of three types of pruning wound were compared in a series of inoculations made between February and the end of December 1957 on a single row of forty 7-year-old dwarf pyramid Cox trees, planted 4ft. apart. The dates of the various sets of inoculations were chosen in relation to the different seasonal conditions of the host trees. Each set of inoculations was confined to the 1955 wood and was replicated among ten different trees, each tree carrying one wound of each type.

The results are given in Figure 1, in which the widths of the columns are proportional to the percentage of successful inoculations (it will be noted that inoculations of terminal and snag wounds in 2-year-old wood were 100% successful on every occasion) and the heights of the columns represent the average lengths of the successful infections of each type of wound, 3 months after inoculation.

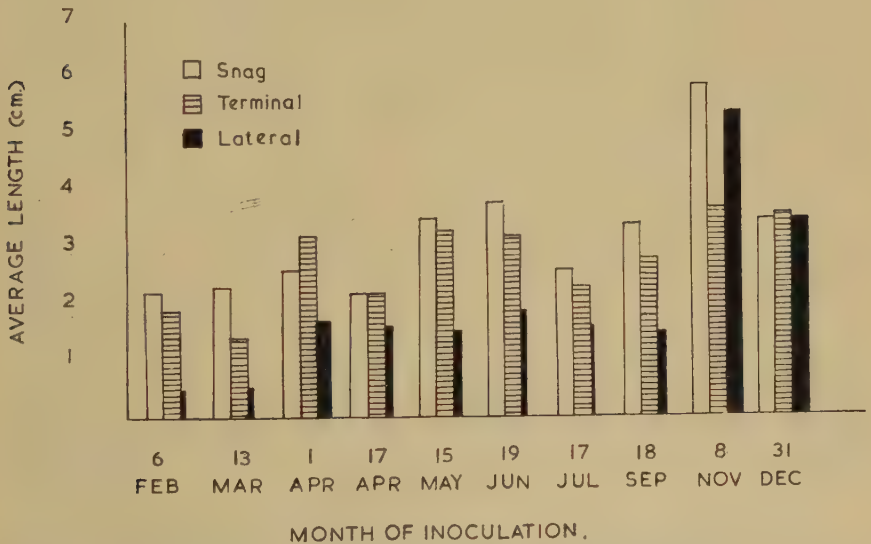


Fig. 1. Relative susceptibility of freshly-made snag, terminal and lateral pruning wounds to *G. perennans*. (Recorded 3 months after inoculation.)

From these data it is clear that the susceptibility of freshly-made terminal and snag wounds is similar at all times of the year on 2-3 year-old shoots. During the spring and summer both these types of wound are considerably more susceptible than freshly-made lateral wounds, and any infections arising from the last type of wound normally remain smaller than those arising from

terminal and snag wounds. When the results of the November and December series are considered, however, it is evident that the susceptibility of lateral wounds during late autumn and winter is comparable with that of terminal and snag wounds; the rate of growth of lesions is also similar irrespective of the location of the wound.

Besides the November and December infections, 40%, 20% and 75% of the lesions of all three types initiated in June, July and September, respectively, showed continued extension throughout the winter of 1957-58. Growth of all the other lesions initiated between February and September inclusive had been arrested by the autumn of 1957.

Age of branch.

The susceptibility of terminal pruning wounds on shoots of different ages was compared in inoculation experiments made on February 6th, July 17th and November 8th, 1957 on a row of thirty-five 10-year-old dwarf pyramid Cox trees, planted 4 ft. apart. In the February series, inoculations were made on branches of three different ages, viz. shoots produced in 1956, 1955 and 1954, while in July and November inoculations on the current season's wood were also included. The inoculations were replicated among ten trees, each tree carrying one complete set of inoculations on wood of each age.

The results, recorded 5 months after initiation of the lesions, are shown in Fig. 2, where the width of the shaded portion of the column is proportional to the percentage of inoculations developing into infections, and the height of the column represents the average length of the successfully established lesions. It will be seen that host resistance to the spread of *G. perennans* decreases as the age of the branch increases and that the percentage liability to infection of terminal wounds made in July is also greater on the 2-3 year-old branches than on younger shoots.

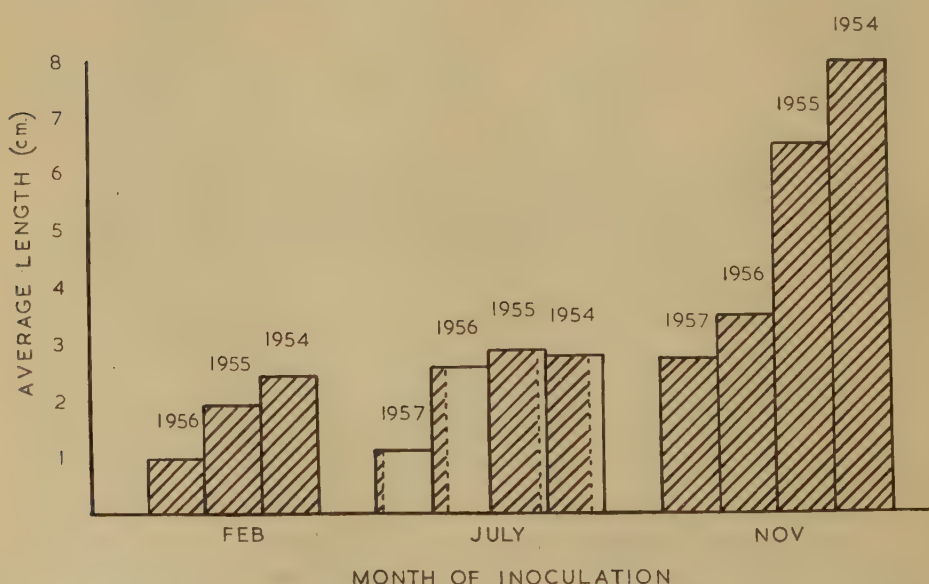


Fig. 2. Effect of age of branch on susceptibility of freshly-made terminal pruning wounds to *G. perennans*. (Recorded 5 months after inoculation.)

All the lesions initiated in February had been permanently arrested by the summer of 1957. In the July series, however, further extension occurred in 10% of the lesions on 1957 and 1956 shoots, while 40% of the terminal wound infections on both 1955 and 1954 branches showed continued extension during the following winter (Plate V, Fig. 1).

Age of wound.

During the inoculation of freshly-made pruning wounds in April, 1956 it was noted that the drops of water containing the spores disappeared in about 15 seconds. By applying a highly concentrated suspension of stained spores to freshly-made wounds and sectioning 24 hr. later, it was demonstrated that the spores were being sucked down the vessels 2 mm. beneath the surface of the wound. In further experiments, carried out in April, July and November 1956, a series of lateral wounds of increasing age (0, $\frac{1}{4}$, $\frac{1}{2}$, 1, $2\frac{1}{2}$, 6 hr., 1, 4, 8, 32 days old) was inoculated with stained spores (500,000 per ml.) while a similar series of wounds was inoculated with viable spores (50,000 per ml.). The depth of penetration of the stained spores was measured after 24 hr. and the numbers of shoot infections resulting from the viable spore inoculations of comparable wounds were recorded approximately 4 months after initiation.

In all three series, the maximum depth of penetration was recorded, on average, about 15 minutes after wounding. Thereafter the effect diminished and wounds made in July no longer showed suction after 6 hr. On the other hand, slight suction was still recorded in 24-hr.-old wounds made in April and November. It was noted that infections arising from viable spore inoculations of wounds of the April and July series did not exceed 1.5 cm. and that only the November series of inoculations developed into typical cankers. The duration of susceptibility to infection in the April and November series of wounds roughly paralleled the duration of the period of active suction. This suggests that the drawing of spores into the vessels below the surface of the wound safeguards the germ tubes produced by the pathogen from desiccation and thus enables the fungus to become established in the xylem, through which the hyphae can spread relatively rapidly (6). Active spore suction has also been shown to be important in the initial establishment of lesions of *Stereum purpureum* in wounds on plum shoots (7).

In the July series, although active suction had ceased within 6 hr., 60% of the inoculations made with viable spores on 32-day-old wounds produced small lesions. During the second 24-hr. period following inoculation, however, 0.4 in. of rain fell, and it is probable that under these moist conditions the spores germinated on the surface of the wounds, producing hyphae which grew down into the vessels and established infections.

The effects of eradicant fungicides on sporulation of cankers of *G. perennans*.

In 1956-7 pilot trials were carried out to examine the possible value of late winter applications of eradicant fungicides, since such measures might provide a practical alternative to the careful excision of shoot infections of *Gloeosporium* in reducing the level of inoculum within an orchard. Two of the fungicides tested, phenyl mercury chloride and sodium penta-chlorophenate, had previously been shown to check sporulation of *Nectria galligena* on established cankers (8).

A preliminary account of the results is given below; further details of this work are to be published later.

1956 *Experiments*. In a preliminary spraying trial at Long Ashton, a 0.3% aqueous suspension of phenyl mercury chloride (PMC) and aqueous solutions containing 0.4% sodium dinitro-*ortho*-cresolate (DNOC) and 0.6% sodium pentachlorophenate (PCP), applied in mid-March 1956, proved ineffective in suppressing sporulation and in checking the spread of mycelium in the host tissue. It was apparent that a more tenacious formulation was required to compare the relative merits of fungicides and in 1956 they were formulated as paints in polyvinyl acetate, which Somers (9) had shown to be an effective sticker. The treatments were as follows:—

- A. 0.3% PMC emulsion paint, prepared by grinding together 0.3 g. of the pure material and 0.6 g. of kaolin and stirring the resulting powder into 100 ml. of polyvinyl acetate emulsion.
- B. 0.6% PCP emulsion paint, prepared by stirring 0.6 g. of the neutral powder into 100 ml. of polyvinyl acetate emulsion.
- C. Polyvinyl acetate emulsion (PVA) without added fungicide.
- O. Untreated control.

This trial was carried out with ninety-six cankers up to 11 cm. in length which had been initiated by pin-stab mycelial inoculations on thirty-two trees of a row of 10-year old dwarf pyramid Cox trees, planted 4 ft. apart. The paints were applied on July 6th 1956. Each treatment was replicated eight times in randomised blocks; each unit plot (1 tree) carried three cankers. The spore output of shoot cankers was measured by collecting spore samples from cankers which were temporarily immersed in water contained by polythene sleeves (Plate V, Fig. 2). The washings from each separate canker were run off through the outlet tube into flat medicine bottles and centrifuged; the average concentration of spores in each sample was estimated from at least four haemocytometer counts.

TABLE I.
EFFECT OF FUNGICIDE PAINTS ON SPORULATION OF CANKERS OF *G. PERENNANS*.
(Paints applied on July 6th).

Sampling date	Weeks after appln.	Mean Spore Production (Multiples of 10,000)				Level of Significance		
		A PMC	B PCP	C PVA	O Control	5%	1%	0.1%
25.7.56	3	0.50	1.91	1.74	7.13	A < O	—	—
8.8.56	5	1.31	1.85	5.18	11.85	A, B < O	—	—
15.8.56	6	0.38	0.40	3.54	4.89	A, B < C	A, B < O	—
22.8.56	7	1.16	2.11	7.92	7.99	B < C, O	A < C, O	—
10.9.56	9½	1.35	4.47	9.98	18.73	B < O	A < C, O	—
3.10.56	13	2.71	4.75	4.86	9.37	no significant differences		
17.10.56	15	0.37	1.18	8.24	2.62	B < C	A < C	—
14.11.56	19	1.25	4.83	10.02	20.26	A < B	B < O	A < C, O
Overall mean		1.02	2.36	5.78	8.83	C < O	A < B	A, B < C, O
Percentage of untreated control		11.6	26.7	65.5	—			

A series of representative samples was obtained between July 25th and November 14th, 1956 (Table I). The results show that both fungicide paints suppressed the sporulation of cankers of *G. perennans* and that PMC was consistently more effective than PCP. This effect continued for at least 4 months; at the end of this period an overall average reduction in viable spore output of more than 88% was still being maintained by the mercury paint. Although some restriction in spore output was recorded in the first 3 weeks for the cankers treated with paint not containing a fungicide, this effect diminished rapidly. Subsequent spore production from these cankers was very erratic.

1957 Experiment. A similarly replicated trial was carried out during 1957 to compare the effect of three different spray formulations of PMC with that of the paint. All the formulations contained 0.3% PMC; they were prepared by grinding the pure material with an equal weight of kaolin, dispersing the powder by grinding with 1.4% methyl ethyl cellulose (final concentration 0.007%) and incorporating the resulting paste in the following formulations:—

- A. Aqueous suspension.
- B. Suspension in 5% polyvinyl acetate emulsion.
- C. Suspension of agglomerated particles in 2% linseed oil emulsion.
- D. Paint in 90% polyvinyl acetate emulsion. (The commercial preparation was thinned slightly to give improved spreading).
- O. Untreated control.

The trial was carried out with 125 cankers up to 5 cm. in length which had been initiated by pin-stab mycelial inoculations, on November 13th, 1956, on twenty-five trees similar to those used in the previous year. The different formulations were applied on March 11th, 1957. Each treatment was replicated five times in randomised blocks; each unit plot (1 tree) carried five cankers. Samples of spore output were taken from June 12th until November 13th, 1957, covering the period of fruit development on the trees.

The results (Table II) showed that spray formulations A and B failed to suppress sporulation after July. The PMC paint was again consistently effective in reducing spore output, and an overall average reduction of over 80% was recorded until mid-September 1957, about 7 months after application. PMC formulated in 2% linseed oil was the most effective of the spray treatments and was generally comparable in its effect with that of the paint formulation. Although its effectiveness dropped slightly below that of the paint after June, no significant differences were demonstrated between these two treatments, and an overall average reduction of 75% in the production of viable spores was maintained. The linseed oil formulation continued to suppress sporulation until the end of October 1957, nearly 8 months after application. None of the treatments inhibited the spread of the fungus within the host tissues.

Discussion.

Recent work (1,6) has emphasized that the life cycles of both *G. perennans* and *G. album*, including their ascigerous stages, may be completed as weak parasites or saprophytes on apple shoots. Infection of the fruit is incidental in the life cycle and, although at present the fruit-rot stage is more important commercially, full control of the disease requires both vigorous eradication of existing tree infections, carried out over several successive seasons, and prevention of the development of fresh lesions. All pruning cuts should be directly

TABLE II.
EFFECT OF DIFFERENT FORMULATIONS OF PMC ON THE SPORULATION OF CANKERS OF *G. PERENNANS*.
(Treatments applied on March 11th).

Sampling date	Weeks after appln.	Mean spore production (Multiples of 10,000)					Level of Significance		
		A Aqueous suspension	B Diluted paint	C Linseed oil	D Paint	O Untreated Control	5%	1%	0.1%
12.6.57 ..	13½	0.93	0.67	0.70	1.07	6.52		A,D<O	B,C<O
26.6.57 ..	15½	0.60	1.21	0.96	1.09	2.92	C<O	A<O	
10.7.57 ..	17½	1.46	1.64	1.08	0.49	4.08	D<O		
19.7.57 ..	19	5.05	2.29	1.02	1.55	5.20	B<A	C,D<A,O	
30.7.57 ..	20½	5.65	1.57	1.73	0.93	5.97	D<A,O		
*7.8.57 ..	21½	4.74	15.77	3.87	1.36	11.77	D<B,O		
15.8.57 ..	22½	3.49	3.16	1.58	0.33	2.57	D<A,B		
28.8.57 ..	24½	2.33	7.72	1.53	0.43	5.19	C<B	D<B,O	
13.9.57 ..	27	2.76	1.83	1.15	0.52	5.09	D<A B<O	C<O	D<O
Overall mean		2.39	2.10	1.19	0.76	4.51		C<B	A,B,C,D<O C,D<A D<B
Percentage of untreated control		53.0	46.7	26.4	16.9	—			

* Non-homogeneous data, omitted from analysis of combined results.

above a bud to avoid the formation of snags that may harbour saprophytic infections. Removal of mummified fruitlets during winter pruning is also advisable, since these may be infected with *Gloeosporium* spp. rather than with the more commonly associated brown rot fungus.

The production of apothecia on detached, infected prunings has been recorded only in small scale experiments. However, since these fructifications produce airborne spores, which may cause widespread dispersal of the disease, it would be an advisable precaution to burn all infected prunings with minimum delay.

Active suction of conidia into freshly-made wounds may play a part in the initial establishment of lesions and it seems probable that, during showery weather interspersed with dry periods, freshly-made wounds are more susceptible than older ones to infection by *G. perennans*. During spells of prolonged humidity, however, there is evidence that wounds up to 1 month old are liable to become infected.

During spring and summer the susceptibility of wounds made by the removal of the distal portion of the shoot is markedly greater than that of wounds produced by excision of a lateral shoot, while the susceptibility of 2-3 year-old branches is greater than that of younger shoots. Thus infections arising from terminal and snag wounds, made during light summer pruning on the current season's wood, are unlikely to develop into serious lesions, but, since susceptibility tends to increase with the thickness of the shoots (6), delayed summer pruning should be avoided. On the other hand, severe dieback infections are likely to follow intensive summer pruning where the excision of older branches is involved (see also Wilkinson (10)).

Where main scaffolding branches are cankered, particularly on young plantings, the rough diseased bark should be scraped away, taking care not to damage the limiting callus; the exposed wood should then be treated either with an emulsion paint incorporating a fungicide, or with a proprietary wound-dressing material. In large trees the painting of individual cankers is laborious and less effective than excision. For small stub infections paint treatment is clearly impracticable and the eradicant fungicide would need to be applied as a spray. So far no commercially suitable fungicide has been found: at the concentrations required (approximately 100 times that used in routine scab sprays) PMC is prohibitive in cost and might prove dangerous to the operator.

For the treatment to remain effective throughout the summer it is essential for an efficient sticker to be incorporated in the spray, and linseed oil emulsion may provide a convenient basic formulation in further trials to find a commercially practicable eradicant spray against *G. perennans*.

Summary.

Sources of orchard infection of *Gloeosporium* spp. are outlined; the influence of age of branch and location and age of wound on the susceptibility of pruning cuts to infection by *G. perennans* are described.

The production of the perfect stage of *G. perennans* on overwintered detached wood infections is recorded.

Results are given of pilot trials of fungicides for suppression of sporulation by stem cankers of *G. perennans*.

Acknowledgments.

The author is indebted to Mr. R. W. Marsh for his constant advice and interest in this work, to Dr. E. Somers for the formulation of the fungicides, to Mr. G. M. Clarke and Miss M. E. Holgate for the statistical analysis of results and to Mr. G. H. Jones and Mr. D. E. Aliband for the photographs. Valuable assistance in the collection of spore samples and in the inoculation work was given by Miss N. M. Waugh.

REFERENCES.

- (1) GUTHRIE, E. J. (1957). *A study of the dispersal of Gloeosporium spp. on apple*. Ph.D Thesis, University of London.
- (2) CORKE, A. T. K. (1955). Bitter rot of apples : I. Branch inoculations with *Gloeosporium perennans* and *G. album*. *Ann. Rep. Long Ashton Res. Sta. for 1954*, 164.
- (3) EDNEY, K. L. (1956). The rotting of apples by *Gloeosporium perennans* Zeller and Childs. *Ann. appl. Biol.*, **44**, 113.
- (4) KIENHOLZ, J. R. (1939). Comparative study of the apple anthracnose and perennial canker fungi. *J. agric. Res.*, **59**, 635.
- (5) BOLAY, A. (1956). Observation en Hollande de la forme parfaite du champignon *Gloeosporium perennans* Zeller et Childs. *Tydschrift over Plantenziekten*, **62**, 322.
- (6) SHARPLES, R. O. (1958). *Gloeosporium disease of apple*. Ph.D. Thesis, University of Bristol.
- (7) BROOKS, F. T. and MOORE, W. C. (1926). The invasion of woody tissue by wound parasites. *Trans. Camb. phil. Soc. (Biol. Ser.)* **1**, 56.
- (8) BYRDE, R. J. W., CROWDY, S. H. and ROACH, F. A. (1952). Observations on apple canker. V. Eradicant spraying and canker control. *Ann. appl. Biol.* **39**, 581.
- (9) SOMERS, E. (1956). Studies of spray deposits : I. The effect of spray supplements on the tenacity of a copper fungicide. *J. Sci. Fd Agric.*, **7**, 160.
- (10) WILKINSON, E. H. (1945). Perennial canker of apple trees in England. *J. Pomol.*, **21**, 180.

OBSERVATIONS ON THE MODE OF PERENNATION OF APPLE MILDEW.

By R. T. BURCHILL.*

The significance of bud infections by mycelium of apple mildew (*Podosphaera leucotricha* (Ell. & Ev.) Salm.) has long been recognised. Woodward (3) in 1927 established that successful perennation of the fungus depended on bud infection during the summer ; once within the buds the hyphae could remain dormant until the following spring when the fungus would rapidly spread to cover the emerging leaves. Little was known, however, about the exact time or method of infection of buds, or the period during which they remained susceptible.

A detailed anatomical study of the incidence and development of mildew infection of the buds on vegetative shoots of apple was therefore undertaken at Long Ashton over a two-year period. The investigation covered the complete cycle from bud initiation to unfolding and included observations on the contiguous petioles, leaves and stems. Another phase of the investigation was the carrying out of a preliminary trial on methods of reducing bud infection by spray treatments.

* This work was carried out during the tenure of a research studentship from the Durham Colleges in the University of Durham.

PLATE V.

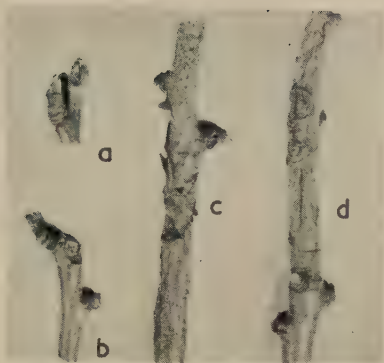


Fig. 1. 6-month-old pruning-wound infections of *G. perennans* initiated in July, 1957. a=1957; b=1956; c=1955; d=1954 wood. (x 0.4)



Fig. 2. Polythene sleeve for washing conidia from stem cankers. Aluminium wire frame pressed firmly into Plasticene at both ends and kept watertight around stem by clips.

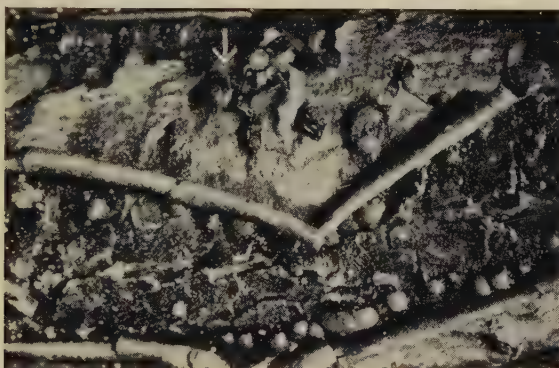


Fig. 3. Perfect stage of *G. perennans* on Allington shoot infection, artificially induced in pin-stab wound (indicated by arrow) in November, 1956. Detached 2 months later and overwintered on grass. (x 4.5)

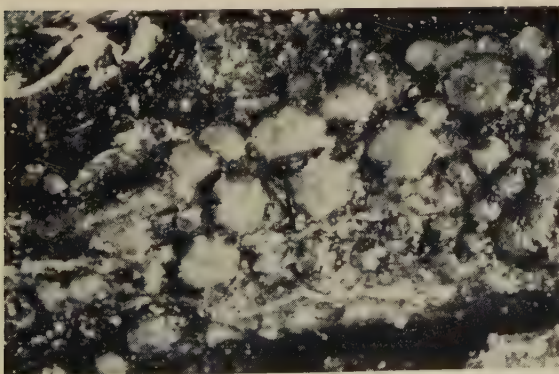


Fig. 4. Perfect stage of *G. perennans* on exposed phloem of artificially-induced pruning-wound lesion on Cox shoot, detached 9 months previously. (x 10)

Experimental.

Site.

Thirty bush trees of the variety Cox's Orange Pippin were selected for studies of bud infection, and a further sixty of the same variety for trials to determine the most suitable time of application of fungicides for mildew control. All the trees were on M. II rootstocks and had been planted 30' x 30' quincunx in 1935.

Weather.

Throughout the period of study the weather was suitable for the establishment of leaf infections. In 1955 mildew attacks were accentuated by a dry period extending from mid-June to September, but in 1956 and 1957 the summer months, after July, were less favourable to mildew, being cool and moist.

Sampling and staining procedure.

Infected and healthy buds were collected from the selected Cox trees at Long Ashton at intervals of a week throughout the summer, and of a fortnight during the winter, from September 1955 to September 1957. They were fixed under reduced pressure in a formalin-aceto-alcohol solution and then stored in 50% alcohol. The material after dehydration and clearing was embedded in wax, sectioned and then stained in safranin and picro-aniline blue solutions according to a modification of the technique devised by Cartwright (1). The sectioned buds were examined for the presence and general condition of the mycelium of *P. leucotricha*. Coupled with these observations examinations were conducted on the incidence and spread of the disease in the plot from which the buds were collected.

Results.

Method of infection.

The observations made during these studies showed that infection of axillary and terminal buds had occurred in the main as the result of the growth of mycelium down the petiole of a subtending infected leaf into the developing buds. The early stages in the infection of a young axillary bud are represented in Figs. 1(a) and 1(b). Fig. 1(a) shows a section of a recently-initiated axillary bud with the scales at the tip still separated; a mildew infection is represented on the adjacent leaf base. In Fig. 1(b) the fungus has spread to the base of the petiole and grown over the surface of the bud scales to reach the interior of the bud. A similar process of infection is shown for a terminal bud in Fig. 2. In Fig. 2(a) mildew is illustrated on the leaves surrounding the bud, and in Fig. 2(b) the infection has spread down the petiole and entered the bud through the spaces between the unclosed bud scales.

Once the mycelium had become established within the bud, it produced conidiophores which later budded off conidia, thereby increasing the degree of infection. Conidia disseminated from other leaves may play some part in this infection (see Figs. 1(b), 1(c), 3(a), 5) but their role appeared to be relatively insignificant in the early summer infections.

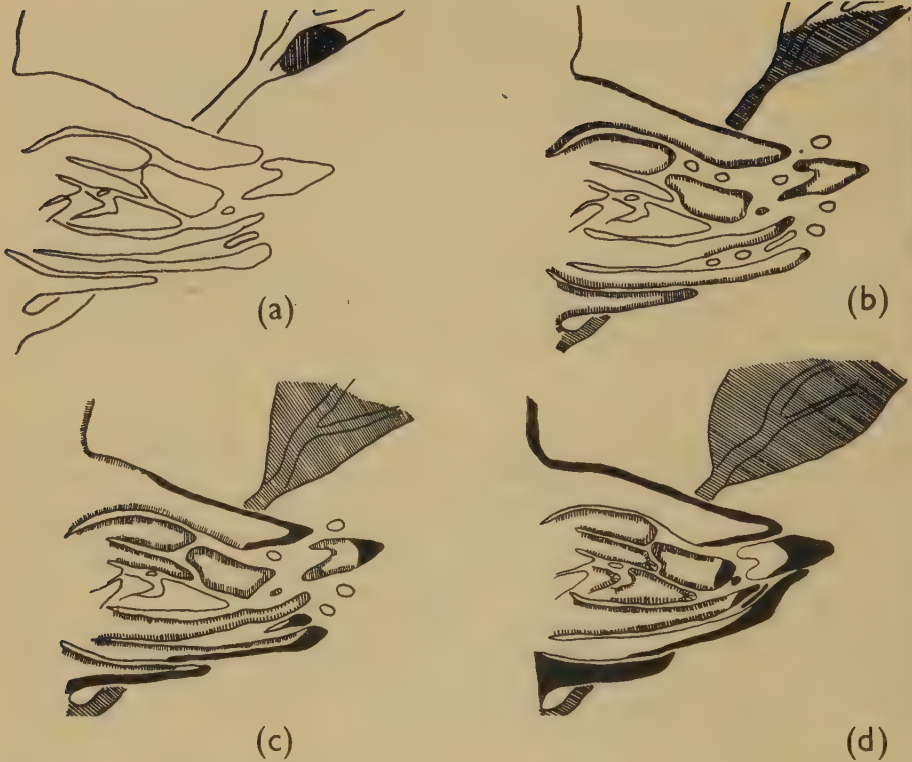


Fig. 1. Stages in the infection of an axillary bud.

- | | |
|--|--|
| (a) Bud in "open" condition; mycelium (shaded) on under surface of lamina. | (b) Spread of mycelium down petiole into bud; entry of conidia from outside. |
| (c) Suberisation of outer scales beginning. | (d) Suberisation complete; bud in "closed" condition. |

Distribution of the disease within the bud.

After the initial entry, the mycelium and spores became concentrated between the outer bud tissues and at the apex of the bud (Fig. 1(b)); at a later period mycelium was also found on the surface of the inner bud scales (Figs. 1(c) and 1(d)) but, if the bud was to survive, hyphae were never found on the apical meristem. Throughout the summer, the distribution of hyphae within the bud was as described above; later, however, the mycelium died out in the outer portions of the bud, becoming confined more to the inner tissues (Fig. 1(d)).

Throughout its existence both on leaves and within the buds, the mycelium derived its nourishment by means of haustoria, inserted into many of the epidermal cells of the host tissue.

In the following spring, when shoot growth was renewed, hyphae rapidly infected all the outer tissues of the bud so that when the leaves emerged they were already covered with fungal mycelium.

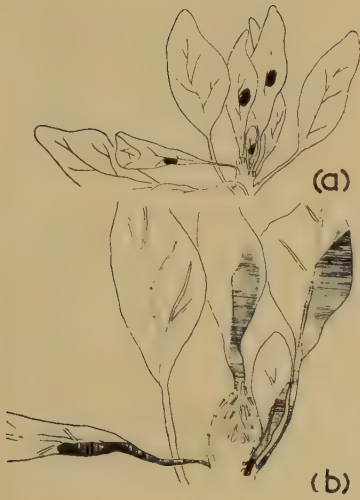


Fig. 2. Infection of a terminal bud.
 (a) Mycelium (shaded) on leaves surrounding bud.
 (b) Spread of mycelium down petiole into open bud scales



Fig. 3. Emergence of infected embryo leaves (3,2,1) from terminal bud shown in Fig. 2.



Fig. 4. Shoot infection arising from terminal bud shown in Figs. 2 and 3.

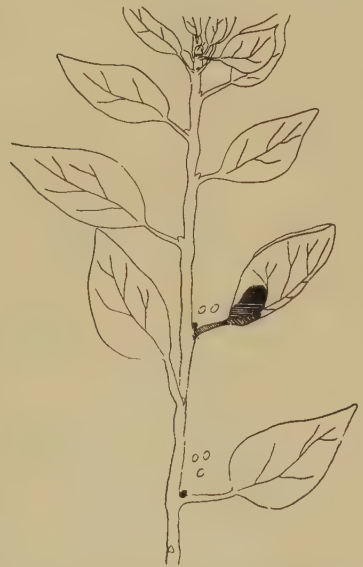


Fig. 5. Shoot with only two axillary buds infected, the upper one by conidia and mycelium, the lower one by conidia only.

Time of infection.

Axillary buds. An axillary bud was susceptible to infection as soon as it was visible within the axil of the leaf. At this time it was in an "open" condition, i.e. the leaf and scale initials were not tightly pressed together; hence mycelium and spores coming from outside could easily reach the interior of the bud (Fig. 1(b)). Three weeks later the outer bud scales began to close around the bud so that at the end of a month it was in a "closed" condition, i.e. the parts were closely packed together and completely enclosed by the bud scales (Fig. 1(d)).

A further barrier to infection was raised by suberisation or bark formation on the outside of the outer bud scales (black areas in Figs. 1(c) and 1(d)). This made it impossible for any mycelium present on these regions to survive, and for hyphae to spread down the petiole into the bud; it also broke the connection between hyphae within and outside the bud (Figs. 1(c) and 1(d)). Once the scales had closed around the bud the hyphae present within were completely protected from any sprays that might be applied.

Suberisation also occurred on the shoot, killing the mycelium present. Such shoots, which were "silvered" as a result of infection, could not, as has been suggested, serve as a means for overwintering of the disease.

As the axillary buds could be infected only while they were young, the earliest formed buds, i.e. those at the base of the shoot, were the first to be infected, and susceptibility to infection then passed successively upwards as the shoot extended and new buds were formed.

Terminal buds. Infection of terminal buds could, however, take place at any time during and just after the period of extension growth, the time of infection determining the amount of mildewed shoot subsequently produced, e.g. an early infection in May resulted in the production of a shoot which was almost completely mildewed (Fig. 6(a)), whereas a later infection produced a shoot with only its apical region attacked. Once a terminal bud was infected, all the subsequently emerging leaves were mildewed, as seen in Figs. 3 and 4 where, as the shoot elongated, the outer embryo leaf (No. 3 in Fig. 3) unfolded to be followed by the other young leaves (Nos. 2 and 1).

Infections of terminal buds could occur so late in the season that the affected buds showed no external symptoms of attack. This was clearly shown on one of the Station orchards (Plot 23) in which a random selection of terminal shoots of Cox was labelled in the autumn of 1956 by a notation similar to that of Foulds and Roney (2). The five grades were:

1. No mildew or very slight attack on the undersurface of some of the terminal leaves.
2. Mildew on terminal leaves only.
3. Mildew on the majority of leaves. Infection of the terminal bud doubtful.
4. Mildew on all leaves and the terminal bud.
5. Mildew on the wood, with shortened internodes.

The percentage of mildewed and dead shoots found in the spring of 1957 on the shoots thus graded in autumn 1956 are shown in Fig. 7. It will be seen that 38% of the apparently healthy shoots (Grades 1 and 2) produced mildewed shoots.



Fig. 6. (a) (b) (c)
 (a) Shoot produced when terminal bud infected midway through growing season.
 (b) Healthy shoot.
 (c) Healthy shoot with only two axillary shoots mildewed.

Only the lightly attacked terminal buds were able to survive the winter and produce a shoot in the following spring. Penetration of the hyphae to the central tissues and the apical meristem invariably led to death. 74% of the buds from severely mildewed shoots (Grade 5), in which such penetration would be expected, were dead at the end of the summer. As with axillary buds, suberisation of the outer scales of the terminals occurred just after completion of the growing season with the same consequences to the fungus.

Fruiting buds. Preliminary examinations of fruiting buds indicated that the period of susceptibility of those formed on dwarf shoots extended for approximately one month between May and early June. Buds occasionally formed on the end of the current season's extension growth were infected at the end of the growing season, while those in an axillary position were infected at a period comparable to the time of infection of vegetative axillary buds.

Spraying trial.

On the block of sixty Cox trees, a preliminary trial was laid out to compare the degree of control of mildew overwintering in blossom trusses obtained by 1% lime sulphur applied at specific times and combinations of times. In 1956 selected applications were made at the green-cluster, pink-bud, petal-fall and fruitlet stages, expressed below as 1, 2, 3 and 4 respectively. Eight lime-sulphur spray programmes were compared, namely: 1, 1+2, 2+3, 1+2+3, 2+3+4, 1+2+3+4, 3+4 and 4. Six trees were used for each comparison and there were also six unsprayed trees and six sprayed with Karathane (25% dinitrocarylphenyl crotonate) at times 2+3 (Fig. 8).

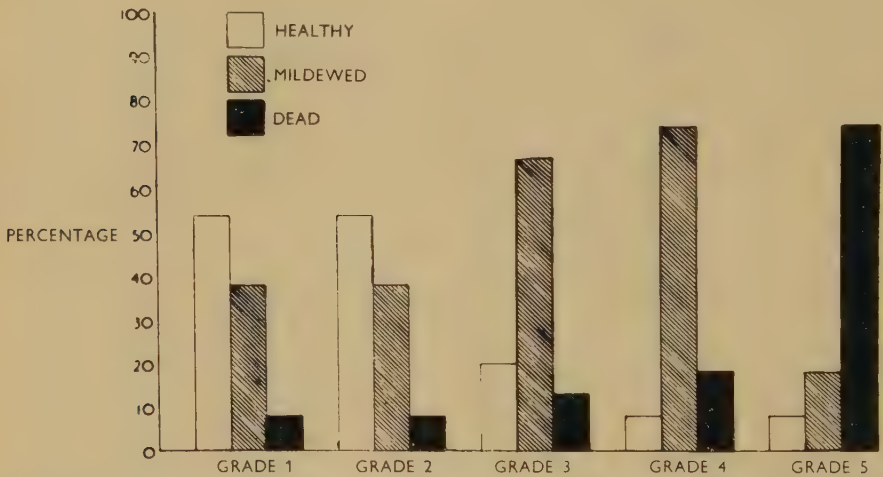


Fig. 7. The percentage of mildewed and dead shoots appearing in spring on Cox shoots graded for mildew infection in the previous autumn. (Grade 1 =no infection; Grade 5 =severe infection).

TABLE I.

EFFECT OF 1956 SPRAY TREATMENTS ON BLOSSOM TRUSS INFECTIONS 1957.
Percentage truss infections recorded May, 1957.

Spray material	Time of application*	Per cent. infection
Control	—	6.3
1% Lime sulphur	1	6.3
	1+2	6.0
	2+3	4.6
	1+2+3	3.3
	2+3+4	1.0
	1+2+3+4	1.6
	3+4	0.6
	4	1.6
Karathane (1 lb./100 gal.)	2+3	2.3

* 1=green-cluster; 2=pink-bud; 3=petal-fall; 4=fruitlet stage.

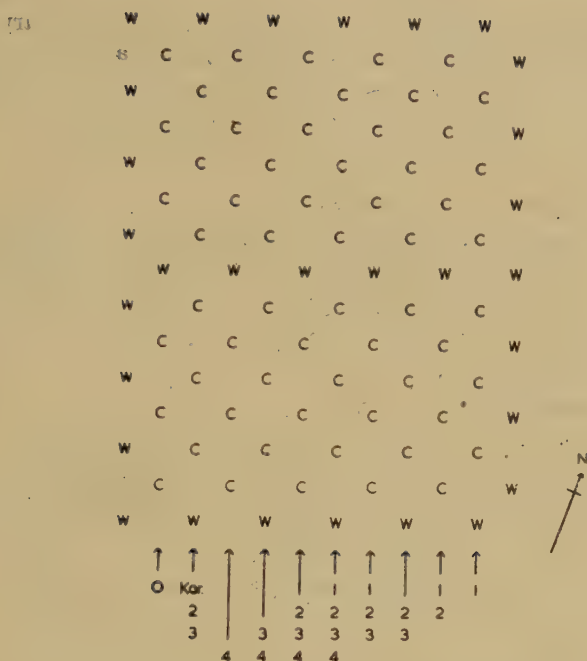


Fig. 8. Lay-out of spray trial.

C=Cox's Orange Pippin ; W=Worcester Pearmain.
1, 2, 3, 4—as in Table I.

Results were assessed by finding the percentage of mildewed trusses in May 1957, to determine the value of these programmes in controlling overwintering infections. The results, given in Table I, show that the lime-sulphur sprays applied before blossoming were ineffective in reducing overwintering mildew, whereas the combination of the petal-fall and fruitlet applications reduced infection to less than a quarter of that in the controls. There was an indication that the Karathane applications were at least as effective as the corresponding lime-sulphur sprays, but this result requires confirmation.

Discussion.

Although these results are in agreement with those of Woodward in regard to the method of perennation of the disease, they indicate that infection of buds can take place at any time throughout the season of shoot extension, rather than during a restricted period. Axillary buds were found susceptible for a period of approximately one month after their emergence; later the closure and suberisation of the outer scales prevented any further infection. Terminal bud infections could occur at any time throughout the growing season and for a short period just after the completion of growth. Early infections led to a distortion of the bud, but very late infections caused no such modification, so that when examined externally the bud appeared to be healthy.

The time of infection of terminal buds is of importance in attempts at control. In the spring of the year following that of infection, axillary buds produced only small distorted leaves which did not provide a large source of inoculum for summer infections. The extension shoots emerging from mildewed terminal buds were the main source of inoculum and consequently it is of the utmost importance that all diseased terminal buds should be removed during the winter.

Under the old method of spur-pruning, the majority of both healthy and diseased terminal buds were cut out, but since the replacement of this system by the renewal and regulated techniques only the terminal buds that are obviously mildewed are removed. The effect of this change on the incidence of mildew in the spring can be readily understood from Fig. 7. In this figure Grades 1 to 5 represent increasing infection with mildew as judged from external appearances. In spur-pruning the terminal buds of all grades would have been removed and consequently there would have been little carry-over of the disease. With renewal and regulated pruning, however, although all the obviously mildewed buds would be removed, those in Grades 1 and 2, which resulted from later infections and which appeared to be healthy, would be allowed to remain on the tree. Consequently there would be a considerable carry over of the disease: 38% of the shoots of both Grades 1 and 2 would appear mildewed in the spring. It appears, therefore, that the increase in the incidence of mildew during the past few years can be attributed in part to this change in pruning systems.

Attempts are now being made to control these late infections by the application of suitable fungicides at the end of the growing season, and by the removal of some of the terminal buds during pruning.

With regard to fruiting buds, the spraying trial (Table I) showed that only post-blossom applications of lime sulphur and Karathane reduced bud infection: pre-blossom sprays were ineffective. Unfortunately, in this trial Karathane was applied only at the pink bud and petal-fall stages and although it gave a better control than lime sulphur at a comparable period, its effectiveness when applied at the fruitlet stage has yet to be determined.

Summary.

The examination of buds of Cox's Orange Pippin has shown that the most important source of bud infection by apple mildew (*Podosphaera leucotricha*) is the growth of mycelium into the buds from infected petioles. The infection of axillary buds is progressive; a bud remains susceptible to mildew attack for approximately one month after emergence. Infection of terminal buds can, however, occur at any time throughout the growing season and just after its completion. Preliminary examination of fruit buds, on dwarf shoots indicates that they are susceptible to infection for approximately one month in the period May-June.

The importance of late infections of terminal buds is discussed in relation to the changes that have taken place in methods of pruning and their effect on the overwintering of the disease and the establishment of new infections in the spring.

A spray trial has indicated the value of post-blossom applications of lime sulphur and Karathane in reducing overwintering mildew in fruit buds.

Acknowledgments.

Grateful thanks are due to Mr. R. W. Marsh for his interest and advice throughout this work, to Mr. C. W. Harper for the spray applications and to Miss M. Waller for assistance in recording. The photographs were kindly taken by Mr. D. Leathers and Mr. D. E. Aliband.

REFERENCES.

- (1) CARTWRIGHT, K. St. G. (1929). A satisfactory method of staining mycelium in wood sections. *Ann. Bot. Lond.*, **43**, 412.
- (2) FOULDS, R. M. and RONEY, E. (1956). Mildew from late secondary infection. *The Grower*, **46**, 359.
- (3) WOODWARD, R. C. (1927). Studies on *Podospaera leucotricha* (Ell. and Ev.) Salm. *Trans. Brit. mycol. Soc.*, **12**, 173.

SPRAY APPLICATION PROBLEMS : XLIV. A COMPRESSED AIR NOZZLE FOR SMALL-VOLUME SPRAYING.

By T. E. COBBALD.

Introduction.

The total area that a given volume of spray is capable of covering is inversely proportional to the arithmetic mean droplet diameter, provided that the spreading factor remains constant over the range of droplet size spectra considered. In terms of spraying this means that if the same or better overall impaction efficiency can be achieved, the smaller the droplets employed the smaller can be the total volume of spray for a given target, without reduction in the total deposit area. This fact is fundamental to the development of small-volume spraying.

The production of a spray from a liquid is essentially a process of distortion accompanied by the creation of a more extensive surface area, the resultant droplets being no more than the stable state of a new surface/volume relationship. This process necessarily absorbs energy, both in overcoming inertia and the viscous forces opposing distortion in the liquid, and, to a greater or lesser extent, in the creation of new surface area. Since the surface/volume ratio varies in proportion to the degree of distortion, this characteristic reflects, both directly and indirectly, the total energy input. But it is this ratio that determines the droplet size spectrum: the greater the ratio, the smaller are the droplets. Thus the finer the spray required, the greater must be the energy input at the point of formation.

Energy is commonly transferred to the site of spray formation in one or more of the following ways: as kinetic energy and elastic energy (compressive strain energy) in the liquid itself, as kinetic energy in associated mechanical apparatus, or as kinetic and elastic energy in an associated fluid. If it is assumed, for the purpose of comparing these three methods, that equivalent delivery tubes are used, then for a given flow rate the kinetic energy of the liquid will be virtually the same in each case, and may henceforth be disregarded.

The simple hydraulic nozzle is a device that relies solely on the energy of the spray liquid to effect atomisation. If the spray produced is not sufficiently

fine for small-volume work, improvement can be brought about only by increasing the elastic energy content of the fluid, and since liquids as a class are not readily compressible this may necessitate the use of very high pressures. This may be undesirable for two reasons: first on account of the mechanical difficulties that will be encountered, and secondly because it involves the use of small (and easily blocked) apertures if flow rates are not to be excessive. It has been shown that the employment of relatively small droplets is a *sine qua non* for effective target coverage by small-volume applications. In practice the hydraulic nozzle does not produce a sufficiently fine spray for all types of small-volume spraying, and the facts given above explain why its shortcomings cannot be easily remedied.

The alternatives to the hydraulic nozzle are those devices in which supplementary energy is transferred to the site of spray formation by one of the other methods described above. Where energy is primarily derived from mechanical apparatus it is most usual to rely upon frictional forces to impart a high centrifugal velocity to the liquid, relative to its point of introduction. According to the design, and the conditions under which the device is operating, so will the size and uniformity of the droplets vary. Other things being equal, the degree of atomisation will depend upon the mechanical power input. The source of this power is in no way critical, other than from the stand-point of transmission efficiency.

The remaining way of applying supplementary energy is to utilize an additional fluid: almost invariably this is air. In contrast to the spray liquid, it may be highly compressed, and in this state it has a high elastic energy content. This is an extremely useful characteristic, which can be made use of in several ways. In addition to assisting in the formation of the spray, it can be employed to propel the droplets towards the target. In full-coverage hydraulic spraying the larger droplets, which have a relatively low surface/volume ratio, perform a dual function. Their initial kinetic energy is such that they can reach the spray target without further assistance, and they there contribute to the final spray deposit. In addition they create and maintain an air current, which helps to sustain and distribute the smaller droplets comprising the lower part of the spectrum. In small-volume spraying the droplets as a whole have a much higher surface/volume ratio, and this phenomenon becomes relatively unimportant. It therefore becomes necessary to induce air currents by other means, since the small droplets will not reach the target areas unaided. Provided that the gross effective kinetic energy output is the same, it is immaterial in theory whether these air currents are achieved by the use of large quantities of air delivered at low pressures, or by smaller quantities of air injected at higher pressures, since entrainment and momentum transfer will exert a levelling influence. Use of the latter method is, however, an attractive exploitation of the high energy capacity of air, in that the same energy throughput is achieved with smaller and more easily manipulated components. It has the further advantage that the energy of the air stream can be employed to continue a process of spray formation that has been initiated by some other means. Air at or near atmospheric pressure has little or no usefulness in this respect.

In the compressed air nozzle the air is employed primarily to effect spray formation, although it may subsequently act as a transporting vehicle, either on its own, or in conjunction with an air stream induced by other means.

The high energy input possible per unit volume of liquid permits a much finer spray to be produced than from a hydraulic nozzle operating at the same liquid throughput.

Kearns and Morgan (1) have described a compressed air spray nozzle for laboratory and field equipment for small-volume airflow spraying. In their design the air is supplied to an annular orifice, within which is situated a coaxial liquid orifice. Air emerges from the annulus at high velocity and at, or slightly above, atmospheric pressure. At a short distance from the nozzle the air jet becomes truly cylindrical, leaving an unfilled conical zone in front of the liquid orifice. In the absence of liquid flow the pressure in this zone is below atmospheric. When liquid is supplied, provided that the actual liquid pressure at the nozzle tip does not exceed atmospheric, it will not tend to extend the boundary of this zone. This condition will be fulfilled only as long as the liquid input does not exceed the capacity of the air to remove it from the conical surface. Up to this point atomisation is reasonably efficient, producing the somewhat dispersed droplet spectrum that is a characteristic of this mode of spray formation. However, if a greater liquid throughput is imposed upon the nozzle, without an increase in the quantity of air, the tendency is for the conical zone to elongate, so that a certain proportion of the liquid is not exposed to the air until it is some distance from the nozzle tip. Under these conditions the velocity of the air relative to that of the liquid is much less than at the annulus rim. This results in the production of coarse droplets, and accounts for the very marked deterioration in spray quality once a certain throughput has been exceeded, despite the fact that the liquid/air mass ratio is not high by contemporary standards.

A more efficient way of achieving good atomisation by means of compressed air is to subject the spray progressively to accelerative forces acting in different directions. This effect is obtained in the nozzle design described below.

The Swirl Mixer Twin Fluid Nozzle.

Basically this nozzle consists of a shallow chamber into which the air is fed through a number of tangential ports. The liquid is introduced through radial ports situated between the air ports. Spray is initially formed at the points where adjacent air jets impinge, and then with the air undergoes centripetal and axial acceleration before leaving the chamber via a single orifice situated in the centre.

A preliminary design is illustrated in Plate VI. A swirl chamber $\frac{1}{2}$ " in diameter and $\frac{1}{8}$ " deep is used, with four $\frac{1}{8}$ " square entry ports for the liquid, and the same for the air. The exit orifice can be $\frac{1}{8}$ " diameter or larger, according to the operating requirements, but should not exceed $\frac{1}{32}$ " in depth. Provided that the supply of the two fluids to the ports is adequately catered for, all other design features and dimensions are non-critical. It will be noted that there are no apertures in the nozzle of less than $\frac{1}{8}$ " diameter, thus making blockage improbable.

The indications are that the chamber should be wide in relation to its depth, and that the exit orifice diameter should be of the same order of size as the chamber depth. Provided that this dimensional relationship is preserved it seems probable that scaling the size up or down can be carried out without loss of efficiency.

TABLE I.
 SPRAY VOLUME DISTRIBUTION AT CONSTANT AIR PRESSURE.
 Orifice Diameter : 0.160 in.

Air		Liquid		Air/Liquid	Droplet Diameters* microns				
Pressure p.s.i.	Flowrate c.f.m.	Pressure p.s.i.	Flowrate g.p.h.	Mass Ratio lb./lb.	D ₁	D ₁₀	D ₅₀ (M.M.D.)	D ₉₀	D ₉₉
80	18.7	67	10	0.84	15	30	55	78	90
80	17.3	70	15	0.52	22	41	72	105	115
80	16.2	72	20	0.36	29	53	90	125	140
80	14.4	77	30	0.22	37	67	115	160	180
80	12.9	81	40	0.14	48	84	140	200	240
80	11.2	83	50	0.10	60	105	175	250	300
80	9.2	85	60	0.069	71	125	220	310	370
80	7.8	88	70	0.050	83	150	260	370	440
80	6.9	91	80	0.039	95	170	300	440	530
80	5.6	95	90	0.028	120	190	340	510	620

TABLE II.
 SPRAY VOLUME DISTRIBUTION AT CONSTANT LIQUID THROUGHPUT.
 Orifice Diameter : 0.125 in.

Air		Liquid		Air/Liquid	Droplet Diameters* microns				
Pressure p.s.i.	Flowrate c.f.m.	Pressure p.s.i.	Flowrate g.p.h.	Mass Ratio lb./lb.	D ₁	D ₁₀	D ₅₀ (M.M.D.)	D ₉₀	D ₉₉
80	12.2	72	10	0.55	17	31	50	66	78
60	9.3	53	10	0.42	22	44	70	95	115
40	6.3	36	10	0.28	30	57	94	125	150
20	3.4	17	10	0.15	48	90	145	200	230

- * D₁—Diameter below which is 1% of the total volume of the spray.
 D₁₀—Diameter below which is 10% of the total volume of the spray.
 D₅₀—Diameter below which is 50% of the total volume of the spray.
 D₉₀—Diameter below which is 90% of the total volume of the spray.
 D₉₉—Diameter below which is 99% of the total volume of the spray.

Some performance figures for the nozzle are shown in Tables I and II. It will be noticed that, for a particular nozzle orifice, the air consumption at a given air supply pressure varies inversely with the liquid throughput. The liquid throughput itself can be varied by adjusting the liquid pressure relative to the air pressure. In one sense that is a useful characteristic, since it means that a wide range of mass ratios is available even without great alteration to the input variables or the nozzle exit orifice dimension. Over the lower part of the operating range the liquid pressure has to be lower than the air pressure. This fact is of practical significance in that no pump is necessary to supply liquid to the nozzles if the liquid tank can be sealed and is capable of withstanding the maximum working air pressure. In Table I the liquid/air mass ratio characterizes the comparative air energy input, as the same air pressure is used throughout. It provides a good illustration of the relationship between energy input and droplet size. This is also demonstrated by the figures in Table II.

PLATE VI.

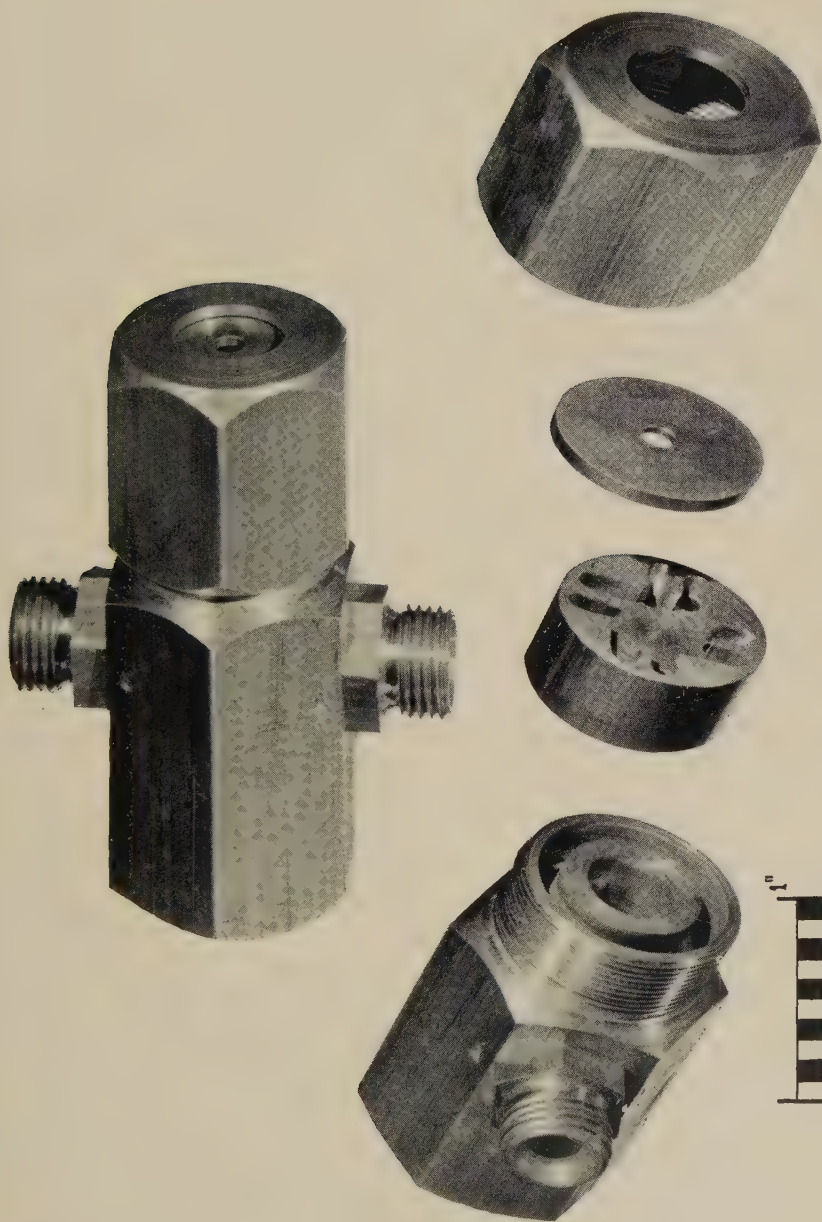


Fig. 1. The twin fluid nozzle, showing assembled nozzle and component parts.

Applications of the Nozzle.

One advantage of operating a twin fluid nozzle at a high gas pressure, i.e. with large energy throughput, is that the one device is then capable of forming both the spray and also, to some extent, the air jet necessary to carry the droplets to a remote target. In some cases it may prove possible to dispense with other means of producing the air jet, such as high or low pressure fans with associated ducting and velocity-recovering nozzles. Such prospects are attractive to the designers and operators of spraying machinery. It is evident that the development of this type of spray machine will be largely governed by the provision of suitable air compressors at not too great a cost. From the technical point of view there is no reason why these should not be available.

Acknowledgment.

I am indebted to Professor H. G. H. Kearns for his encouragement and interest in the development of the nozzle described.

REFERENCE.

- (1) KEARNS H. G. H. and MORGAN N. G. (1956). Spray application problems: XXVIII. A compressed air spray nozzle for laboratory and field equipment for small-volume air flow spraying. *Ann. Rep. Long Ashton Res. Sta. for 1955*, 146-150.

SPRAY APPLICATION PROBLEMS: XLV. THE PERFORMANCE OF A POWER KNAPSACK MIST SPRAYER.

By T. E. COBBALD.

The success achieved by aircraft and large ground sprayers in the application of small volumes of concentrated spray materials has led to the development of small-power machines capable of being carried on the back of the operator in a similar way to the pneumatic knapsack sprayer. While some produce fogs of very small droplets by thermal means, others atomise a fluid into small droplets by means of high velocity air. A machine of the second type, representative of a number of makes giving somewhat similar performances, has been examined. It consists essentially of a high-speed lightweight 2-stroke engine which drives a centrifugal fan; the air from the fan atomises the spray liquid into a stream of droplets that can be directed at will by the operator.

A description of the machine is given, together with details of the droplet spectrum produced and of the distribution resulting from the application of a copper spray to a potato crop and to apple and plum trees.

Technical Description.

The engine and fan are mounted on a sub-frame of pressed sheet steel, attached by means of flexible rubber mountings to a tubular frame that forms the knapsack chassis and rests on the operator's back. The flexible mountings

serve to protect the operator from the vibrations of the engine. The fan is driven by twin-V belts, the tension of which can be regulated by means of an adjustable cam which determines the position of the engine relative to the fan. The discharge duct from the fan is brought out at the bottom of the sub-frame on the right-hand side of the operator.

Two metal straps, with quick-release fasteners, are fitted at the top of the main frame for the attachment of a cylindrical spray liquid tank and a fuel tank. The spray tank is fitted with an air-tight filler cap, a discharge pipe and a pressure tube connecting with the fan duct.

The discharge duct from the fan is turned through 90° in the horizontal plane, so that it is close to the operator's right elbow. The middle portion of the duct is enlarged and lined with sound-absorbent material. It also embodies a small open-ended tube facing into the air-flow; this provides the air pressure tapping for the spray liquid tank.

The air is taken via a wide flexible pipe from the right-angled duct to a short length of rigid pipe, which terminates in a venturi nozzle. The spray liquid flows separately to the throat of the venturi through a small bore plastic tube, partly by gravity, and partly on account of the difference in pressure between the tank and the venturi throat. Control of the liquid flow is by means of interchangeable restrictor orifices and an on-off cock, which is mounted on the rigid pipe. The liquid is introduced to the air stream through a small open-ended tube which enters the venturi throat obliquely to the direction of air flow and projects slightly more than half-way across. The spray is formed solely by the shearing action of the air on the liquid film that forms around the extremity of this tube.

The venturi nozzle is provided with a short parallel extension to which may be fitted a conical diffuser with a screen of expanded metal. This presents a series of angled slots to the air stream, causing it to be deflected away from the axis of the nozzle proper. In addition to the liquid control there is a cable control of the engine throttle, the lever being placed on the main frame at a point accessible to the operator whilst he is carrying the machine.

Brief Specification.

Engine. Single-cylinder two-stroke air-cooled dry-sump petrol engine; bore 4 cm.; stroke 4 cm.; swept volume 50 c.c.

Fan. Centrifugal; 5.6" diam. rotor with 12 backward curving blades.

Transmission. Twin V-belts; drive ratio, engine/fan = 1/3.7 approx.

Container capacities. Fuel tank 0.335 Imp. gall.; spray tank 2.464 Imp. gall.

Weight. Empty 31 lb.; loaded 56 lb. (approx.).

Performance.

Fan output. The performance of the machine is largely dependent on the output from the fan; therefore the performance of this unit is critical. Other things being equal, the air output from the fan was found to be proportional to the speed of rotation. The maximum speed attainable was dependent upon the engine torque available and the pneumatic loading. When the diffuser was fitted to the machine the maximum fan speed was approximately 17,500 r.p.m. corresponding to an engine speed of approximately 4,750 r.p.m. The volumetric displacement under these conditions was in the order of 120–125 cubic ft./min.

measured as free air. Without the diffuser the resistance to air flow was less, resulting in a volumetric displacement of some 135-140 c.f.m., with a slightly reduced peak engine speed. With these outputs the mean air speed through the venturi nozzle ranged from 360 to 410 ft./sec., i.e. from 250 m.p.h. to 280 m.p.h. The slowest speed at which the engine would run satisfactorily was about 2,750 r.p.m., at which rate the air output was in the order of 70-75 c.f.m. with the diffuser fitted, and 80-85 c.f.m. without it. Mean air speeds through the nozzle venturi then ranged from 140 m.p.h. to 170 m.p.h.

The form in which the fan rotor blades are shaped causes the unit to be self-limiting in its power demand. This prevents any overload on the engine, even at maximum air throughputs. On the other hand, the free flow of air should not be severely restricted, since this will interfere with the proper cooling of the engine.

Heat from the engine, and frictional losses in the fan and ducting, caused the efflux air to be somewhat above ambient temperature. With the engine running at maximum speed, and the air flow throttled back by the nozzle diffuser, the temperature difference was approximately 55°F. for ambient temperatures from 60°F to 110°F. The significance of this temperature difference, in relation to the actual spray formation, has not been determined.

Fuel Consumption.

The consumption of fuel (a petrol/oil mixture of 16:1) varied considerably according to the working conditions. The maximum rate, when operating on full throttle and with the spray nozzle and diffuser fitted, was approximately 0.22 gallons per hour. At this rate one filling of the fuel tank lasted approximately $1\frac{1}{2}$ hours. The corresponding figures for lower speeds are given in Table I.

TABLE I.
FUEL CONSUMPTION.

Engine speed (r.p.m.)	Fuel/lubricant consumption (gall./hr.)	Approximate running time per tank filling (hr.)
4,750	0.22	1.52
4,500	0.18	1.86
4,250	0.15	2.23
4,000	0.13	2.57
3,750	0.12	2.79
3,500	0.11	3.05
3,250	0.10	3.35

When the diffuser was not fitted the fuel consumption tended to be slightly greater at speeds over 3,500 r.p.m. and slightly less at speeds below this figure. This difference is of little practical significance, since the variation at any point did not exceed 5%.

Spray Output.

The restrictor orifice fitted in the spray delivery tube affords only a partial control of the liquid flow, since this varies in accordance with the pressure differential across it. This is in turn determined by the level at which the nozzle

is held relative to the liquid level in the spray tank, and by the tank pressure and the nozzle induction. These last two variables are influenced by the operating speed and by the presence or absence of the diffuser.

The maximum total air pressure difference, obtained at maximum speed without the diffuser, was approximately 36" water gauge : the sum of 28" w.g. pressure head and 8" w.g. induction head. When the diffuser was fitted there was a substantial reduction in the nozzle induction, but this was in part compensated for by a slight increase in tank pressure. Table II shows the flow rates for water through the three restrictor orifices supplied with the machine, at three venturi positions.

If liquids of higher viscosity than water are sprayed, the throughput will be reduced.

TABLE II.
FLOW RATES ; WATER (GALL./HR.).

Restrictor orifice	Engine (r.p.m.)	Nozzle position *					
		Without diffuser			With diffuser		
		High	Level	Low	High	Level	Low
No. 1 5" 64	3,000	3.7	6.5	8.8	3.6	6.4	8.8
	3,500	4.8	7.4	9.6	4.4	7.1	9.3
	4,000	5.8	8.3	10.4	5.2	7.8	9.8
	4,500	6.9	9.2	11.2	6.0	8.5	10.4
No. 2 7" 64	3,000	7.8	12.0	15.0	7.5	11.7	14.0
	3,500	9.3	13.1	16.0	8.8	12.6	15.6
	4,000	10.8	14.2	17.0	10.0	13.5	16.4
	4,500	12.3	15.3	18.0	11.2	14.4	17.2
No. 3 9" 64	3,000	12.4	20.0	25.5	12.0	19.6	25.4
	3,500	15.2	22.1	27.5	14.3	21.2	26.9
	4,000	18.0	24.2	29.5	16.5	22.9	28.3
	4,500	20.6	26.2	31.4	18.7	24.6	29.8

* "High" - 18" above fan outlet ; "Level" - Level with fan outlet ;

"Low" - 18" below fan outlet.

Spray Droplet Spectra.

The character of the spray formed is determined by the conditions at the nozzle venturi. The variables chiefly concerned are the air speed and the liquid flow rate, over both of which the operator has control. Within the normal operating limits, an increase in air speed and/or a reduction in the liquid flow rate will reduce the Mass Median Diameter of the spray ; a decrease in air speed and/or an increase in the liquid flow rate will have the opposite effect.

The presence of the outlet diffuser complicates matters in that some of the spray liquid is deposited on the upstream side of the screen, and sheared off into droplets again on the downstream side. Since the air speed at this point is less than at the nozzle venturi, the M.M.D. of these secondary droplets will be greater than that of the primary spray. Thus, other things being equal, the introduction of the diffuser results in an increase in the M.M.D. of the spray.

A reduction of the surface tension of the spray liquid, by means of a suitable additive, will cause a lowering of the M.M.D. of the spray. Liquids containing suspended solids can be successfully comminuted, as can light and heavy oils. Table III shows the results of several M.M.D. assessments, made with the machine working at normal operational settings, using water, water and detergent, a water suspension of copper carbonate with a detergent, a kerosene and a spindle oil.

TABLE III.
DROPLET SIZE.

	Engine speed (r.p.m.)	Air speed (ft./sec.)	Spray liquid	Liquid flow rate (g.p.h.)	M.M.D.* (microns)
Without diffuser	3,400	300	Water	12.5	270
	4,700	400	"	12.5	103
	3,400	300	"	6.5	117
	4,700	400	"	6.5	92
With diffuser	3,800	300	Water	12.5	295
	4,500	350	"	12.5	150
	3,800	300	"	6.5	235
	4,500	350	"	6.5	113
	4,500	350	Water+0.25% Manoxol N	12.5	105
	4,500	350	Water+0.25% Ethylan CP+0.5% copper carbonate	12.5	132
	4,500	350	Odourless kerosene	12.5	102
	4,500	350	Risella oil (P. 31)	12.5	168

* Mass Median Diameter : a diameter such that 50% of the volume (mass) of the spray consists of droplets of diameter greater than the M.M.D., 50% of droplets of diameter less than the M.M.D.

At the lower operational air speed of 300 ft./sec. there is a tendency for the droplet size frequency curves to be of a double-peaked form. This suggests that two methods of droplet formation are operating : (i) the drawing and disruption of thin liquid films into droplets of <300 microns and (ii) the disengagement of accumulated liquid masses equivalent to droplets of 500-600 microns. The wide spectrum produced results from overloading conditions at the nozzle venturi and/or the diffuser screen. If a reasonably homogeneous spray is required, then it may be necessary to specify the maximum flow rate and the minimum engine speed.

Air Jet.

Irrespective of whether the diffuser is fitted or not, the air leaving the machine behaves in the usual manner of a submerged jet, with a discharge cone of approximately 23-24° included angle, and with a diminishing mean velocity as the area of diffusion and the degree of entrainment increase. Table IV shows the peak velocity, as measured on the jet axis, at different distances from the venturi. Away from the axis of the jet the velocity is less.

These figures are of significance in relation to the free-falling terminal velocity of the spray droplets. The droplets cannot move horizontally any faster than the velocity of the air stream that surrounds them, which must be considerably greater than the droplets' downward velocity if any appreciable

TABLE IV.
AIR VELOCITY GRADIENT.
(Maximum engine speed. Diffuser fitted).

Distance from Venturi (ft.)	0	1	2	4	6	8
Peak air velocity (ft./sec.)	410	66	37	19	13	7

lateral movement is to be achieved. Thus the "carry" of the machine depends partially on the air output, and partially on the droplet size generated. The homogeneity of the spray will be reflected in the evenness of the spray distribution. Droplets of over 300 microns diameter have a terminal velocity of over 8 ft./sec. and may be expected to fall out of the air stream within a short distance of the machine.

Field Performance.

A small field trial was carried out to gain some experience with the machine in applying a particulate fungicide to a mature potato crop. A spray containing a basic carbonate of copper with a copper content of 2.5 per cent., ten times that of 10-12.5-100 Bordeaux mixture, was applied at the rate of $4\frac{1}{2}$ gallons per acre. Seven rows, 30" apart, were treated in one pass, the operator walking down the middle and swinging the nozzle from side to side above the crop. The diffuser was fitted in order to deflect the spray downwards on to the plants. The rate of application was approximately $1\frac{1}{2}$ acres per hour. As soon as the spray deposit on the leaves was dry, random samples were taken from plants over the full width of the swath. The copper content of these samples was determined by colorimetric analysis.

Over 99% of the spray deposit occurred on the upper leaf surfaces. The very small amount of copper deposited on the undersides of the leaves was found mainly on the plants in the centre of the swath. A visual examination of the leaves was sufficient to show that the deposit on the tops of the plants was very much greater than that at the bottoms. Together with the absence of under-leaf deposit this indicated that the degree of air turbulence at plant level was low, and that deposition took place mainly by sedimentation. Table V shows the mean deposit per unit leaf area over the 4 zones of the swath, as defined by distance from the centre line.

TABLE V.
COPPER DEPOSITS ON POTATO FOLIAGE.
($\mu\text{g. Cu/cm.}^2$).

Zone	Mean distance from centre line (ft.)	Mean deposit	Maximum deposit
I (Row 4)	0	7.96	118
II (Rows 3 & 5) ..	2.5	4.48	95
III (" 2 & 6) ..	5.0	5.10	118
IV (" 1 & 7) ..	7.5	0.98	27.5

The very considerable difference between the mean and the maximum deposits in each zone is chiefly due to the concentration of the deposit on the upper parts of the plants, and shows how difficult it is to obtain an even deposit in compact foliage when using small-volume methods. The low deposit in the outermost zone (IV) suggests that under field conditions a swath width of only 5 or 6 rows could be satisfactorily sprayed.

The influence of foliage density on the levels of the deposit is also illustrated in Table VI, which gives the results of a trial of the machine on apples and plums, two trees of differing foliage characteristics, using 5 gall. per acre of the same copper spray. There is a generally lower level of deposit on the plum leaves, and a preponderance of deposit on the more exposed foliage. In this table the separate analysis figures for the outer and inner zone deposits serve to demonstrate the filtering effect of the peripheral foliage.

TABLE VI.
COPPER DEPOSITS ON APPLE AND PLUM LEAVES.
($\mu\text{g. Cu/cm.}^2$).

	Sub-sample	<i>Apple</i> 40' circum.; 12' high; open structure; sparse foliage		<i>Plum</i> 40' circum.; 16' high; closed structure; dense foliage	
		Outer Zone	Inner Zone	Outer Zone	Inner Zone
Top third of tree	(a)	16.3	10.3	3.0	1.0
	(b)	49.5	7.3	2.3	1.0
	(c)	44.5	13.8	19.0	0.8
	(d)	40.0	11.0	2.3	1.5
Middle third of tree	(a)	51.0	21.5	7.3	1.3
	(b)	49.5	15.5	9.8	1.0
	(c)	79.5	12.5	11.3	1.3
	(d)	8.3	28.8	9.0	5.8
Bottom third of tree	(a)	99.0	11.8	2.5	1.8
	(b)	32.5	73.0	33.0	4.5
	(c)	32.5	20.0	52.5	6.0
	(d)	59.5	46.0	22.0	4.3

Discussion.

The general conclusion to be drawn from these tests is that a power knapsack mist sprayer is best suited for applying small volumes of spray liquids per acre to crops offering little resistance to the passage of air through them, and where biological considerations do not demand a high degree of uniformity of deposit. The uniformity of distribution will, as in the case of hydraulic sprayers, depend largely on the skill of the operator.

Acknowledgment.

I am indebted to Mr. H. R. Mapother for the deposit analysis.

THE ACTIVITY OF PECTIN METHYLESTERASE IN BLACK CURRANTS: PROGRESS REPORT.

By MARGARET E. KIESER, A. POLLARD & D. J. SISSONS

The high pectin content of black currants has made the use of pectin degrading enzymes necessary in juice extraction. Treatment of the milled fruit with such enzymes normally gives, after a period of reaction, a breakdown of pectin in the pulp and a reduction of viscosity sufficient to allow pressing to proceed. Although the method has been in commercial operation for many years, certain factors remain ill-defined, for the efficiency and speed of depectinisation may show variations in practice (1). These are to be expected because of differences in the quality and content of the pectin in the fruit and the pH of the juice, according to variety and state of ripeness. Variations in composition due to manurial effects and to seasonal influences (2,3) have already been reported. Pretreatments of the fruit, such as heating or storage, will introduce additional variables such as, for example, changes in the enzymes of the fruit itself.

Although the amount of pectin present has been shown to be affected by factors such as those given above, the type of pectin present has not been studied in any detail nor have the pectin enzymes of the fruit itself received much attention since Euler and Svanberg demonstrated the presence of pectin methylesterase in black currants in 1919 (4). The readiness with which the milled or crushed black currants set to a gel is an indication of the presence of this enzyme, and tests made at Long Ashton some years ago confirmed that the enzyme was present in black currants. The results, however, showed certain anomalies, and estimation of enzyme activity by methods found suitable for apples (5) appeared less satisfactory for black currants. Further tests of an exploratory nature were made in the 1957 season and these will be briefly described.

Experimental Results.

Pectin changes in milled black currants.

Black currants of the variety Mendip Cross were harvested at the commercial-ripe stage when the strigs contained some incompletely coloured berries. The fruit was brought immediately to the laboratory, strigged and rapidly minced. The pulp was placed in covered containers at room temperature and samples were taken for pectin analysis at intervals over a period of 22 hours; there was no visible evidence of mould growth or of fermentation.

Each sample (100 g.) was extracted at pH 3 with a solution (300 ml.) of sodium hexametaphosphate (Calgon, 0.3%) at 80° for 1 hour. The extract was filtered through muslin and the solid residue again extracted twice successively with water (300 ml.) at 80° for $\frac{1}{2}$ -hour. The extracts were filtered through a thin layer of paper pulp with filter aid (Hyflo Supercel) and the combined filtrates made to volume (1 litre). Aliquots were precipitated with acetone (60%) for subsequent determination of total pectin (6) and of its degree of esterification by titration (7).

The results shown in Table I indicate that the amount of pectin extractable with water decreased slightly after the first hour and more appreciably after

22 hours. The degree of methylation of the pectin extracted also decreased, suggesting that pectin demethylation, presumably by pectin methylesterase, had proceeded extensively even at the low pH of the fruit (2.91). This was confirmed by the increasing viscosity of the pulp on standing.

TABLE I.
PECTIN CHANGES IN BLACK CURRANT PULP.

<i>Time of standing</i>	<i>Extractable pectin (as % calcium pectate)</i>	<i>Esterification of pectin (as %)</i>
20 min.	1.232	82.7
30 min.	1.250	79.8
1 hr.	1.100	79.5
3 hr.	1.063	76.1
22 hr.	0.904	58.0

The extraction of pectin methylesterase.

An enzyme extract prepared from a sample of the same fruit by methods similar to those used for apple tissue (5), and involving disintegration of the fruit in sodium chloride-phosphate buffer at pH 7.0 in the presence of toluene, showed pectin methylesterase activity, but at a low level (Table II). Alternative methods of enzyme extraction were therefore studied, the water-soluble and water insoluble portions of the fruit being tested separately.

A sample of the same fruit (400 g.) was disintegrated coarsely by brief mincing in a Waring Blendor with distilled water (400 ml.) and the skin and seed fraction separated by squeezing through muslin. The fine cellular debris passing through the muslin was separated from the juice by centrifuging, washed with water and the aqueous solutions were combined to give a diluted juice fraction (b). The cellular material was extracted twice with sodium chloride-phosphate buffer at pH 7.0 (150 ml. and 75 ml.) and the extracts were combined (c). The skin and seed fraction was extracted similarly (d). The two extracts (c) and (d) and the juice fraction (b) were tested for the presence of pectin methylesterase by noting their capacity to gel a pectin solution at pH 6.5. Fraction (d) appeared to be inactive: fractions (b) and (c) were highly active and were examined quantitatively (5).

As shown in Table II, fraction (c) showed an activity more than ten times higher than that previously found for the whole fruit (a): the juice fraction (b) also showed a higher activity than the fruit but the greater part of the enzyme was associated with the cell debris (fraction (c)). Extracts prepared subsequently from a frozen sample of the same black currants showed a lower total activity and a different distribution of activity between soluble (b) and insoluble (c) pulp fractions. In an over-ripe sample of Amos Black there was a more equal distribution of activity between these pulp fractions.

The pectin methylesterase of freshly-picked black currants thus appears to be associated mainly with the insoluble cell-wall material of the fruit, as found also for apple (5) and for many other plant tissues (8,9). In both fruits, however, some part of the enzyme can become solubilised or at least dispersed effectively in the juice. The present results show, moreover, that the enzyme in black currants is accompanied by inhibitory substances, or by substances that give rise to inhibitors, in extracts prepared from the whole fruit. A similar effect

TABLE II.

PECTIN METHYLESTERASE (PME) IN BLACK CURRANTS.

Variety	Fraction	PME activity (units*)
1. Mendip Cross	{ (a) Whole fruit	0.28×10^{-4}
	(b) Juice	0.87×10^{-4}
	(c) Cell debris	3.64×10^{-4}
2. Mendip Cross stored frozen ..	{ (b) Juice	1.0×10^{-4}
	(c) Cell debris	0.4×10^{-4}
3. Amos Black over-ripe	{ (b) Juice	0.43×10^{-4}
	(c) Cell debris	0.34×10^{-4}

*1 unit = 1 m. equiv. methanol liberated per g. fruit per min.

has been noted in apples, for buffer extracts of acetone-extracted apple tissue show a higher pectin methylesterase activity than do extracts of whole fruit (10).

It is probable that the phenolic components of the fruit are involved in the black currant as they are in apple. The inhibitory effect of apple juice components and tannin upon mould polygalacturonase was noted in earlier work (11), confirming the findings of Mehltz and Maass (12). More recently, the effects of oxidised apple phenolics upon the macerating enzyme system of the Brown Rot fungus (*Sclerotinia fructigena*) have been described by Byrde (13). Oxidised catechins have again been stated to inhibit pectin methylesterase in tea fermentations (14). Other recent work by the authors has shown that preparations of apple phenolics markedly inhibit apple pectin methyl esterase and that the leucoanthocyanin present in perry pears (15) effectively inhibits at a low concentration a range of pectic enzymes including pectin methylesterase from apple and polygalacturonase enzymes from yeasts and moulds (16). Later work may show that a number of phenolics exhibit this effect to varying degree according to their capacity to precipitate proteins.

Discussion.

It is thus evident that pectin breakdown in black currant juice production can be influenced by a number of factors, and the efficiency of the process under commercial conditions may well show variation. The presence of pectin methylesterase derived from the fruit should normally assist the action of added pectin-degrading enzymes: it has indeed been shown (10) that a yeast polygalacturonase, inactive against fully methylated pectin, readily breaks down the pectin in black currant pulp when the native pectin methylesterase is also present. Conversely, inactivation of the fruit enzyme by heat may limit the effectiveness of added enzymes and explain some of the difficulties experienced in the depectinisation of canned black currants (1). It is possible, however, that excessive pectin hydrolysis in the fruit before enzyme addition—as might occur in damaged or long-stored fruit—could lead to inefficient pectin removal due to its partial insolubilisation as the calcium salts of pectinic acids.

The presence of natural enzyme inhibitors in black currants may prove to be an additional cause of variation during processing operations. In the tests described the presence of such substances, or of their precursors, did not appear to hinder the hydrolysis of pectin in the milled fruit (Table I). It is possible that the inhibitory effects noted in fruit extracts arise mainly by subsequent changes in the phenolic components of the fruit.

REFERENCES.

- (1) REID, W. W. (1950). *Recent Advances in Fruit Juice Production*, (Chap. XI), Techn. Comm. No. 21, Commonwealth Agric. Bureaux.
- (2) BRYAN, J. D. and POLLARD, A. (1948). *Ann. Rep. Long Ashton Res. Sta. for 1947*, 216.
- (3) KIESER, M. E., POLLARD, A. and STONE, A. M. (1950). *Ann. Rep. Long Ashton Res. Sta. for 1949*, 159.
- (4) EULER, H. and SVANBERG, O. (1919). *Biochem. Z.*, **100**, 271.
- (5) POLLARD, A. and KIESER, M. E. (1951). *J. Sci. Fd Agric.*, **2**, 30.
- (6) CARRE, M. H. and HAYNES, D. (1922). *Biochem. J.*, **16**, 60.
- (7) KERTESZ, Z. I. (1951). *The Pectic Substances*, p. 234, Interscience Publishers, New York.
- (8) *Ibid.* p. 366.
- (9) HOLDEN, M. (1946). *Biochem. J.*, **40**, 103.
- (10) Unpublished data.
- (11) KIESER, M. E., POLLARD, A. and STONE, A. M. (1950). *Ann. Rep. Long Ashton Res. Sta. for 1949*, 153.
- (12) MEHLITZ, A. and MAASS, H. (1935). *Biochem. Z.*, **276**, 86.
- (13) BYRDE, R. J. W. (1956). *J. hort. Sci.*, **31**, 188; *Ibid.* (1957), **32**, 227.
- (14) RAMASWAMY, M. S. and LAMB, J. (1958). *J. Sci. Fd Agric.*, **9**, 46.
- (15) KIESER, M. E., POLLARD, A. and WILLIAMS, A. H. (1953). *Chem. and Ind.* 1260.
- (16) POLLARD, A., KIESER, M. E. and SISSONS, D. J. (1958). *Chem. and Ind.* (in the press).

STORAGE OF FROZEN BACON, BRAWN AND VENISON.

By MARGARET STURDY and ALICE CRANG.

Traditional methods of storing home-cured bacon necessitate a concentration of salt too high for present-day tastes and cool storage conditions that are hard to find in many modern homes. As an increasing number of home-freezers are now being used, tests were made to compare the quality of bacon stored by freezing with that kept in a cool cellar.

Salt is known to accelerate the onset of rancidity. Since frozen pickled pork and salted sausages have been found to turn rancid more quickly than comparable unsalted pork or sausagemeat (1), in the present tests some of the pork was frozen immediately and cured after storage for comparison with the frozen bacon. The effects of maturing the bacon in the light or dark before freezing, of smoke flavour as a possible anti-oxidant, and of wrapping the bacon in polythene instead of greaseproof paper for cool storage, were also tested.

The rate of deterioration of frozen brawn was investigated, since the quantity made from a pig's head is often more than that required for immediate consumption. The effect of aging was also noted in the tenderness and flavour of a series of venison chops held for 5, 7, 10 or 12 days before freezing.

Experimental.

Bacon.

In each series of tests, both sides of the loin were received the day after the pig was killed; they were divided as evenly as possible into the requisite number of joints of about $1\frac{1}{2}$ –2 lb. weight, immersed 10 minutes in cleansing brine, drained, wiped, and either packaged in polythene bags overwrapped with mutton cloth for immediate freezing, or else cured by the graduated cure

method (2) for medium or long storage. The losses in weight during curing and storage were noted. The joints were tested as follows :—

- A Sealed in polythene bags and frozen one day after killing ; removed from the freezer about a week before required for tasting ; thawed and then cured.
- B Cured, wiped free of surplus salt, wrapped and frozen without a period for maturing.
- C₁ Cured as in B, but hung to dry for 10-15 days in a light room, average temperature 57°F., away from direct sunlight.
- C₂ Treated as in C₁ but shielded by a black cloth over greaseproof paper during the drying period.
- D₁ Cured and matured in a light room, as in C₁, then wrapped in greaseproof paper and hung in a linen bag in a cool, dark cellar for storage.
- D₂ Cured and matured in the dark, as in C₂, then wrapped and stored as in D₁.
- E₁ Treated as in D₁ with substitution of sealed polythene bag for greaseproof paper.
- E₂ Treated as in D₂, but stored in a polythene bag as in E₁.

The joints were removed from the freezer and allowed to thaw in their containers for a day ; they were soaked in 3 changes of water and left overnight before simmering in fresh water until cooked. The bacon stored in the cellar had the skin and bone surfaces scraped and a thin layer cut off the other surfaces, to remove any mould, before soaking.

In *Series I* (1956) the loins were divided into 8 joints. Joints given treatments A, B, or C₁ were stored for both 17 and 32 weeks ; those given treatments D₁ or E₁ were stored for 17 and 32 weeks respectively. A medium cure (5 days per inch of thickness) was given.

Series II (1956) was used to test different concentrations of commercial Smoke Flavour C7618. The joints were given treatment C₁ but, after maturing and before freezing, duplicate joints were painted with 10 ml. of alcohol containing either 0.07, 0.14 or 0.28 ml. of smoke flavour, whilst two controls were painted with alcohol only. The bacon was judged 9 and 29 weeks after killing to test the effect of the different smoke concentrations, the second tasting being judged at the same time as the bacon stored 32 weeks (*Series I*).

In *Series III* (1957) all the treatments A to E₂ were given, but the smoke flavour was omitted. Three loins were used : two were given a medium cure (5 days per inch thickness of loin) and judged after 12 and 21 weeks, whilst the third was given a hard cure (8 days per inch thickness) and judged 44 weeks after killing.

Brawn.

Brawn was made from a pig's head, trotters and beef using the recipe in *Home Curing of Bacon and Hams* (2). Waxed cartons were filled with approximately 9 oz. of pickled meat and 7 fl. oz. of stock, held in a cool store overnight to set and then frozen ; the brawn was withdrawn at intervals of 4, 8, 12, 16 and 26 weeks, thawed and tasted.

Venison.

Four loin chops were cut from a carcase 5 days after killing. One chop was sealed in a polythene bag and frozen the same day, the others were hung in

muslin to age 7, 10 or 12 days after killing, and sealed in polythene before freezing. The last two chops had to be placed in a cold store at 38°F. to complete aging as the weather turned mild. The chops were thawed, cooked in casseroles in a rich brown sauce and compared after a total of 19 weeks' storage.

Method of Judging.

The marks given for colour, texture and flavour were based on the following score :—

- 5 Excellent colour or texture, unusually full and rich flavour.
- 4 Very good colour, texture or flavour.
- 3 Average colour or texture, normally good flavour.
- 2 Slightly too pale or dark, slightly tough, rather weak flavour.
- 1 Too dark or pale, too tough but passable, very weak or slightly foreign flavour but not objectionable.
- 0 Too poor to be passable.

The tasting panel usually consisted of five to eight people, but it was enlarged to fifteen for the 12 weeks' storage test in 1957, by the inclusion of those attending a meat preservation course.

Results.

Bacon.

Table I gives a comparison of the quality of the bacon after the different treatments and storage from 12 to 44 weeks.

The frozen pork, thawed and cured just before tasting (A), was satisfactory in appearance throughout the series; the mild immature flavour was preferred by some of the panel, but considered lacking in flavour by others, especially in the larger panel. It was rated the best of the series after 17 and 32 weeks' storage.

The bacon frozen immediately after curing (B) gave a similar mild flavoured bacon, acceptable to all and considered the best of the series after 44 weeks storage in 1957, although in 1956 the joint stored for 32 weeks showed slight rancidity at the edges of the fat. The lean throughout lacked any pink colour.

There appeared to be no advantage in maturing the bacon before freezing. The rancidity noted in treatment C₁ after 17 and 32 weeks was probably due to the polythene containers becoming torn in the freezer. The effect of drying the bacon under a black cloth was tested because Sumner (3) reported that oxidative rancidity was produced in fats and oils by blue, violet and ultra violet radiations and that the fats became rancid only on exposure to light. These present tests, however, showed little advantage in drying the bacon in the dark (C₂) over drying in the light (C₁) before freezing.

The bacon cured, dried and stored in a cool cellar developed the characteristic "home-cured" flavour that was liked by some of the tasting panel during the shorter periods of storage, but disliked by others. The hard cured bacon, tasted after 44 weeks, was considered too salt, and the fat of that dried in the light was rancid. Maturing the bacon in the dark seemed to delay rancidity, but for long keeping this method of storage is far less satisfactory than freezing.

TABLE I.

BACON STORAGE TESTS—SERIES I AND III.

Average score (maximum 5) and general comments.

Treatment	Series	Total Storage (weeks)	Colour (inside)	Texture	Flavour	General comments
A	III	12	3.4	3.2	2.8	Satisfactory appearance, very mild flavour.
	I	17	4.0	3.5	3.0	Satisfactory appearance, mild flavour: best of this series at 17 weeks.
	III	21	3.6	2.8	2.6	Outside appearance poor, lean a little tough, mild flavour.
	I	32	3.0	3.0	3.0	Appearance quite good, flavour acceptable, but not mature: best of this series at 32 weeks.
	III	44	3.4	1.6	3.1	Tough, otherwise satisfactory.
B	III	12	2.5	2.9	2.1	Lean rather pale, satisfactory texture, flavour very mild.
	I	17	2.5	3.0	2.5	Lean grey, fat a good colour, flavour acceptable but treatment A preferred.
	I	32	1.5	3.0	1.5	Outside fat yellow, inside white with grey lean, lean acceptable but fat slightly rancid.
	III	44	3.4	3.5	3.5	The best of this series at 44 weeks.
C ₁	III	12	2.9	1.5	2.0	Texture tough or a little stringy, rather tasteless but acceptable flavour.
	I	17	2.0*	1.0*	1.0*	Good lean but tough, yellow streak in fat and slightly rancid.
	III	21	3.5	2.7	2.2	Outside colour rather yellow, inside good, lean hard, flavour acceptable to most.
	I	32	1.8*	1.0*	0.5*	Lean a good colour and acceptable flavour, but fat yellow and rancid.
	III	44	3.4	2.4	2.8	Good inside colour, lean tough, flavour acceptable to most.
C ₂	III	12	3.3	2.2	2.1	Satisfactory appearance, flavour generally acceptable.
	III	21	2.4	3.0	1.8	Outside fat yellow, inside fairly good, very variable remarks on flavour.
	III	44	3.3	2.8	2.8	Outside fat yellow, inside good, flavour acceptable to most.
D ₁	III	12	2.2	1.5	2.2	Outer fat yellow, bacon tough, typical "home-cured" flavour liked by some but not others.
	I	17	2.0	1.4	2.0	Lean good colour but fat yellow; tough, typical "home-cured" flavour liked by some but not others.
	III	21	2.3	2.2	2.0	Outer fat very yellow, but inner colour acceptable, lean tough, typical "home-cured" flavour.
	III	44	1.4	0.8	1.1	Colour poor, very tough and stringy, too salt, fat rancid.

* Containers damaged in the freezer.

TABLE I—*continued*.

BACON STORAGE TESTS—SERIES I AND III.
Average score (maximum 5) and general comments.

Treatment	Series	Total Storage (weeks)	Colour (inside)	Texture	Flavour	General comments
D ₂	III	12	2.2	2.0	1.5	Outer fat yellow, inner fat acceptable, rather tough, typical "home-cured" flavour.
	III	21	1.8	1.7	1.1	Outer fat yellow, inner fat just acceptable, lean tough, flavour not generally liked.
	III	44	2.0	1.6	2.6	Better than D ₁ stored for 44 weeks.
E ₁	III	12	2.2	2.3	2.1	Outer fat yellow, some mould, typical "home-cured" flavour.
	III	21	—	—	—	Very thick mould and very objectionable smell: not tasted.
	I	32	—	—	—	Very thick mould and very objectionable smell: not tasted.
	III	44	—	—	—	Very thick mould and very objectionable smell: not tasted.
E ₂	III	12	—	—	—	Very thick mould and very objectionable smell: not tasted.
	III	21	—	—	—	Very thick mould and very objectionable smell: not tasted.
	III	44	—	—	—	Very thick mould and very objectionable smell: not tasted.

Sealing the bacon in polythene instead of wrapping in greaseproof paper for home storage was found to be unsatisfactory, as putrefactive bacteria and undesirable yeasts and moulds developed after 12 weeks' storage, rendering the bacon inedible.

Treating the cured bacon in Series II with smoke flavourings in the concentrations used had no effect on flavour and did not prevent the onset of rancidity, there being no appreciable difference between the three lots of treated bacon and the control when judged after 9 weeks; all were considered slightly rancid after 29 weeks' storage.

Although relative losses in weight during the curing and drying of the small joints used in these tests are greater than those to be expected from larger joints, the figures are of interest in comparing the different treatments. Mean losses, expressed as percentage fresh weight, were as follows in the various processes.

Curing	13
Curing and drying in the dark	17
Curing and drying in the light	21
Curing and drying in the light, storing in greaseproof paper 12 weeks	25
Curing and drying in the light, storing in greaseproof paper 21 or 44 weeks	27
There was no loss due to freezing the bacon, provided that the containers were not damaged in the freezer. But bacon stored in greaseproof paper in a cellar becomes hard and dry on the outside and is usually covered with a layer of mould, so that there is a further loss in cutting off the outer layer before the bacon can be cooked.	

Brawn.

The flavour of the brawn was a little over-salt for some tasters, but declared very good by others. No rancidity or loss of weight was recorded up to 16 weeks' storage, although the flavour after 12 weeks was not quite so good as that stored for shorter periods. After 26 weeks' storage some rancidity was detected at the edges of the pack, and this was accompanied by a loss in weight of 0.35%. The waxed boxes were, therefore, satisfactory only for the shorter storage period; the probable maximum storage for good quality brawn is four months.

Venison.

The chop frozen immediately after cutting up, 5 days after killing, was rated slightly tough and lacking in flavour and considered the poorest in flavour, whilst that aged for 12 days was very tender and rated the best by four of the tasters, but had too strong a flavour for the other four. Preferences for the various periods between killing and freezing were (i) 10 days, (ii) 12 days, (iii) 7 days, (iv) 5 days.

Summary.

Tests on the freezing of home-cured bacon, brawn and venison have shown that:—

- (1) For long keeping, frozen bacon was preferred to that stored by the traditional method; it was also less wasteful.
- (2) Frozen matured bacon developed rancidity of the fat more quickly than bacon frozen immediately after curing.
- (3) Bacon frozen without maturing kept satisfactorily for eight months provided the wrapping was efficient.
- (4) The addition of smoke flavours at three different concentrations to mature bacon before freezing did not prevent the development of rancidity, nor did it improve the flavour of the bacon.
- (5) Sealing home-cured bacon in polythene bags for home storage encouraged the growth of putrefactive organisms.
- (6) Frozen brawn was satisfactory up to 12 weeks.
- (7) Venison should be aged before freezing, the time depending on individual preference; a few days less than that required for fresh meat will suit most palates.

REFERENCES.

- (1) STURDY, M. and CRANG, A. (1956). *Ann. Rep. Long Ashton Res. Sta. for 1955*, 188–195.
- (2) *Home Curing of Bacon and Hams* (1943). M.A.F. Bull. 127, H.M.S.O., London.
- (3) SUMNER, W. (1953). *Food*, **22**, 253–255.

CRICKET BAT WILLOWS: SALE AND UTILIZATION OF THE LONG ASHTON TREES.

By K. G. STOTT.

Cricket bat willows (*Salix alba* var. *caerulea*) were first planted at Long Ashton by H. P. Hutchinson in 1928; by 1934 about 100 trees had been planted. Most of these had reached the minimum requirement of 48 in. breast height girth by 1950, but an opportunity for their disposal did not arise until the winters of 1956 and 1957 when they were purchased direct by a firm of cricket bat manufacturers. Five trees were sold in 1956 when, thanks to the courtesy of the buyer, it was possible to follow the conversion of their timber into clefts. In 1957 fifty two trees were sold. Details of this sale, including the volumes of produce and costs of conversion, are given below in the hope that they will be helpful to growers with trees nearing maturity.

Long Ashton Plantation.

Site. The layout of the Long Ashton plantation is shown in Fig. 1, in which the site of each tree is numbered. The trees occupied the floor of a narrow valley with a gentle slope and northerly aspect at an elevation of 100 ft. A block (Plantation) of 34 trees, planted in 1934 (1) and covering approximately one acre, filled the head of the valley, from which an avenue of 24 trees stretched down to the north. At its northern end a single line of 6 trees ran eastwards across the valley. A little to the north was a single row of 5 trees planted in 1928.

The soil is a reddish loam derived from Keuper Marl with added alluvium and colluvium. Drainage is good and normally the water table is below 3 ft., but due to the narrowness of the valley and the steepness of its sides, hill wash and surface streams occur in times of heavy rain. The rows of willows were situated beside shallow ditches designed to take away this surface water. Occasionally a nearby stream overflowed through the plantation but, despite these facts, the site would normally be regarded as dry for bat willows.

It is protected by the local configuration from the prevailing winds, but is a moderately bad frost pocket.

Climate. The climate at Long Ashton is wetter, less sunny and more equable than that of Essex where most of the cricket bat willows are grown. There is, however, no marked difference in the seasonal distribution of rainfall in the two areas. Annual means are:

	Rainfall (in.)	Sunshine (hr.)	Winter Temp.	Summer Temp.
Long Ashton	36.39	1529	43.7°F	56.5°F
Essex	23.73	1670	42.5°F	57.3°F
	(Earls Colne)	(Clacton)	(Halstead, near Colchester)	

Description of Trees.

Trees felled in 1956. The 5 trees felled in 1956 were planted in 1928 as 4-year-old unrooted sets 20 ft. apart (2, 3). In 1956 their mean height was over 80 ft., their mean breast height girth (B.H.G.) 63.7 in. and boles were 11 ft. 6 in.

high to the first branch. Their average annual girth increment was 2.0 in. throughout their life: it was 2.65 in. during the period 1928-1932 and had fallen to 1.5 in. by 1955. Maturity was probably reached in 1943.

These trees realized £60 or £12 per tree.

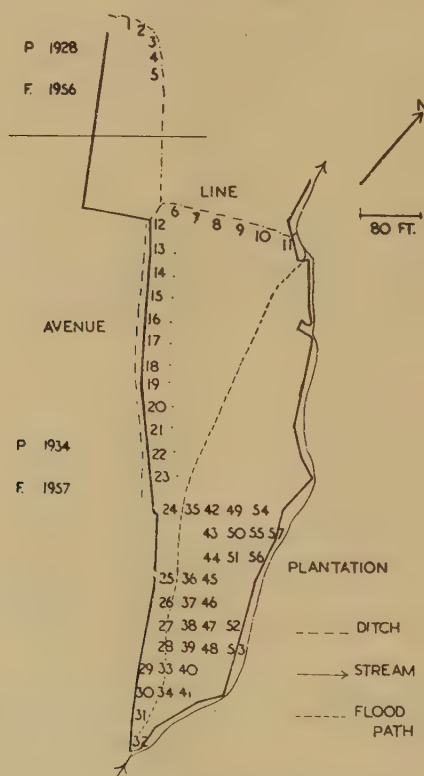


Fig. 1. Bat willow site, Long Ashton.

Trees felled in 1957. These consisted of 34 Plantation trees, 6 Line trees and 12 trees forming the westerly row of the Avenue. All had been planted 30 ft. apart, using 2-year-old sets of $\frac{1}{2}$ -1 in. diameter, raised by methods described by Hutchinson (4). The trees had been topped when young at about 8 ft.; side branches were produced from this point and at maturity the trees had a straight branchless bole of about 8 ft., above which four or five straight stems, 30 ft. long, reached up at a narrow angle. The trees were large, averaging 80 ft. in height and 55 in. B.H.G. (Fig. 2). 10 trees had made poor growth and were only 41.8 in. B.H.G.; the remaining 42 averaged 58 in. and of these 14 were over 60 in. B.H.G.

The 52 trees were sold for £450 or £8 8s. 0d. per tree.

Allowing for the age of the set the trees were 25 years old when felled. The mean girth increment in their last year was only 1.4 in., the narrowness of the annual rings showing that growth had been poor for several years. In common with many plantings made in the early 1930's the trees were planted too close together, and lack of light was probably the factor most responsible

for their slow growth : spacings of 35-45 ft. are now recommended (5). The trees were pollarded with the object of making them more wind-firm by reducing their upward growth. In fact, branching produced a dense crown that was less able to resist winds (5) : pollarding is not now recommended.

The 34 Plantation trees had narrow crowns and due to competition for light the pollarded stems had grown up cleanly and almost vertically to about 80 ft. The ill effects of close planting were more pronounced than in the Avenue or Line trees, and in the last two or three years damage by the Honey fungus, *Armillaria mellea*, had become increasingly noticeable. The 12 Avenue trees were healthy, but five had been pollarded at 6 ft. 6 in. and contained only two rounds of cricket bat timber in the bole. The 6 Line trees were larger, with a greater length of clean bole, and for their size they had more but smaller pollard stems than the other trees.

The dimensions of the different groups of trees and records of the timber obtained are given in Table I.

Utilization.

In timber sales the buyer has a right to all the timber, though he may be interested only in part. Only the basal part of the bole, rarely exceeding 10 ft. in length, is suitable for cricket bat production ; the large amount of timber in the rest of the tree is often regarded as worthless. While buyers are prepared to travel 200 miles to collect the boles, they seldom find it economic to transport the tops. In East Anglia and the Home Counties, they find it just pays, at £5 per ton, to transport this material 50 miles to chip board mills at Sittingbourne, Kent. This market is too distant from Western growers, who have found buyers reluctant to clean up the site and leave it tidy. In the 1957 sale particular attention was therefore paid to the utilization of the tops.

The Long Ashton trees were particularly large, and a considerable amount of timber remained after the cricket bat bole had been extracted (Fig. 4). The lower portions of the straight upright stems were found useful as basket wood, i.e. suitable for the manufacture of the veneer used in making chip baskets (Fig. 5). The remaining material, consisting of the smaller branches, straight poles and brushwood, was in part (trees 6-11) converted to pulp-wood at the hardwood pulp mills at Sudbrook, Monmouthshire (Fig. 6), while the rest (trees 12-57) was sold for firewood.

Cricket Bat Timber.

Quantity.

The lower portion of the branch-free bole is suitable for clefting when trees have reached 48 in. B.H.G. Clefs must be 26-28 in. long, hence the bole is first cross cut into lengths (rounds) of 28 in. (Fig. 4). The fifty-two Long Ashton trees felled in 1957 averaged 8 ft. of clean bole, measured to the first large branch. 25 of the trees produced three rounds, 13 two rounds, 13 four rounds, and eight rounds were obtained from one that had not been pollarded. 3 rounds were rejected, leaving a total of 158 rounds, or 3 rounds per tree. The rounds weighed 12 tons $2\frac{1}{2}$ cwt.

Quality.

Sapwood and grain. The quality of boles is dependent on a number of factors of which the most important are the radial width of white sapwood and

TABLE I.

MEAN DIMENSIONS AND PRODUCE PER TREE.

	1956	1957			
		Line	Avenue	Plantation	Total or Mean
Number of Trees felled	5	6	12	34	52
Site (Fig. 1)	1-5	6-11	12-23	24-57	6-57
Age (years)	32	25	25	25	25
Length of bole					
Range ..	13' 10"-10' 6"	9' 6"-8' 6"	10' 0"-5' 0"	11' 6"-5' 0"	
Mean ..	11' 6"	9' 0"	7' 3"	8' 1"	8' 0"
Breast height girth (inches)					
17.2.55 —Range ..	71.0-54.0	—	—	—	—
—Mean ..	62.2				
28.11.55 —Range ..	72.0-55.5	77.0-54.0	65.0-42.0	65.0-35.5	
—Mean ..	63.7	59.3	52.5	52.9	53.6
6.11.56 —Range ..		78.0-56.0	67.0-42.0	65.0-37.5	
—Mean ..		61.3	54.4	54.1	55.0
Girth Increment (inches)					
17.2.55-28.11.55		28.11.55-6.11.56			
Range ..	2.0-1.0	2.0-1.5	2.5-1.5	2.5-0.5	
Mean ..	1.5	2.0	1.9	1.2	1.4
Bat Timber (rounds)*					
Range ..	5-4	4-3	4-2	8-2	
Mean ..	4.2	3.5	2.6	3.2	3.1
Basketwood (vol. Hoppus ft.)					
Range ..	—	19.5-0	—	—	5.8
Mean ..		5.8			
Basketwood (pieces)+					
Range ..	—	—	5-0	7-0	
Mean ..	—	—	1.7	2.5	2.3
Pulpwood (pieces)ø					
Range ..	—	63-30	—	—	—
Mean ..	—	42	—	—	—
Firewood (cords)	—	—	½	>1	1

* Round = 28 in. length of bole.

+ Piece (basketwood) = 8 in. quarter girth, 7 ft. long.

ø Piece (pulpwood) = over 3½ in. diameter, 4 ft. long.

the straightness of the grain. Clean white sapwood is associated with fast grown trees, and is said to be indicated by the amount of golden brown inner bark visible on the bole. At least 5 in. of white sapwood on the radial face of the cleft is needed to make a first class bat 4½ in. wide.

The timber should be perfectly straight in the grain and free from blemishes caused by irregularities in growth, pests and diseases. The best quality is obtained from the lowest round, and trees with branch-free boles measuring 3 or 4 bat lengths are preferred. Rounds obtained from further up the bole are often spoilt by the distortion of the grain caused by large branches, and are suitable only for boys' bats. In six trees that produced four rounds, however, a round was obtained from the main trunk above the first large branch.

Coloration due to heartwood, stain and damage. In well-grown trees the heartwood is a pale brown colour and is restricted to a small central area. On the clefts and bat-face it shows as a marginal uniform vertical band which, though slightly detrimental to the appearance, detracts little from the value unless very extensive.

The quality of many trees is spoilt by the presence of stained timber. Most of the Long Ashton trees contained a certain amount of stain which occurred as a deep yellow-orange discoloration in the periphery of the heartwood, extending outwards into the sapwood as star-shaped projections; it also occurred in blotches within the heartwood zone. When present at the foot of the basal round the stain usually extended throughout the bole and was visible on the upper cut at 7 ft. 6 in., but here the ray projections tended to disappear and the stain followed the annual rings in more or less concentric circles. Sometimes the upper rounds showed only heartwood coloration (Fig. 7).

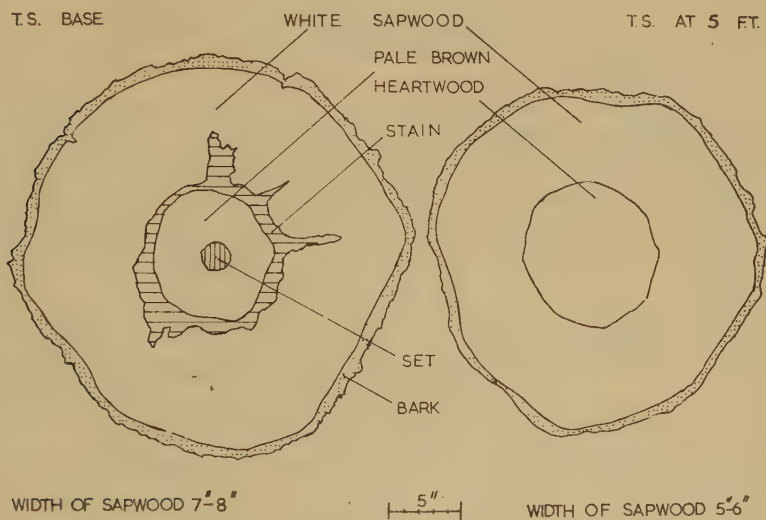


Fig. 7. Distribution of stain in Tree No. 1.

Where these irregularities occurred it was difficult to find 5 radial inches of white sapwood, even though the tree was large; thus in one tree with a basal diameter of 21 in. the width of white sapwood averaged only 3 in. In badly stained trees these irregularities may reach to within 1 in. of the bark; the stain then appears on the longitudinal face of the cleft or bat as dark horizontal bars with lighter wings. It has been stated that when this "bar stain" is present in large patches its position is shown by horizontally cross-cracked swellings on the bark, which on the radial face of clefts can usually be traced back to a pruning cut or other wound in the set (1, 5, 6, 7, 8, 9, 10); to avoid this source of stain special methods of raising sets have been devised (4). None of the cross cut faces of the Long Ashton rounds showed any relation between ray projections and deformities in the bark.

Badly discoloured sapwood was associated with fire damage in one tree and with *Armillaria mellea* in a number of others. Bat willows are usually grown in lines and on short rotation; severe attacks of *Armillaria* are therefore commonest in old plantations with reduced vigour and slow growth; at Long Ashton they were confined to the overcrowded Plantation. In 6 trees the quality of the wood was seriously impaired; a further 4 trees were slightly damaged.

In slight attacks the only external evidence was the death of small branches in summer, but removal of the bark at the base disclosed the white mycelium. The outer sapwood was stained yellow but the heartwood did not appear to be affected. The mycelium enters the bole via the root spurs and, even when the attack and discoloration were restricted laterally to a small sector of the tree, the discoloration extended vertically into the branches. In more advanced stages the bark had fallen off, revealing the white mycelium and black rhizomorphs; the sapwood was cracked, stained dark brown, and the discoloration extended into the heartwood zone (Figs. 9 and 10). Since *Armillaria* attacks from the outside, the presence of only a slight yellow discoloration in the sapwood very seriously reduces the value of the tree.

Estimates of quality.

(i) *By measurement.* The breast height girth of the trees sold in 1957 was measured before felling. The maximum and minimum diameters of the discoloured heartwood zone and of the white sapwood annulus were determined on the rounds of each tree when cross cut. Mean values for 28 trees producing from two to four rounds each are given in Table II. The bark averaged $\frac{3}{4}$ in. in thickness.

TABLE II.

SAPWOOD AND HEARTWOOD IN TREES GIVING TWO TO FOUR BAT ROUNDS.

Trees	Dimensions*		Rounds numbered from base	Sapwood, unstained (radial width, inches)		Heartwood (diameter, inches)	
				Range	Mean	Range	Mean
<i>Four rounds</i>							
9, 10, 11,	62.9 in. G.		1	6.9-3.6	5.7	13.9-10.1	11.7
26, 27, 28,	20.0 in. D.		2	5.8-3.8	4.6	10.9- 9.6	10.2
30, 53	9 ft. 4 in. L.		3	5.1-3.4	4.1	10.4- 9.8	9.9
			4	4.6-3.2	3.9	11.2-10.0	10.6
<i>Three rounds</i>							
6, 7, 8, 22, 31,	54.8 in. G.		1	7.2-3.9	5.4	10.5- 8.8	9.5
34, 37, 38, 39,	17.4 in. D.		2	5.8-3.5	4.1	9.6- 9.0	9.2
41, 49, 50, 51	8 ft. 2 in. L.		3	4.2-3.0	3.6	9.3- 8.8	9.0
<i>Two rounds</i>							
2, 36, 42,	57.5 in. G.		1	8.2-2.9	6.2	10.4- 7.1	8.7
52, 54,	18.4 in. D.		2	5.4-3.4	4.8	9.4- 8.4	8.8
55, 57	8 ft. 1 in. L.						

* G,D. = girth and diameter at 4ft. 3 in.; L = length of clean bole.

The range in the width of white sapwood is due not only to irregularities in the central heartwood or in the stained zone but also to the fluting of the bole caused by large root spurs; many of the trees giving only two rounds were also elliptical in cross section.

For first-class clefts, rounds with an average of 5 radial inches of white sapwood are required. It will be seen that all the basal rounds fall into this category together with parts of the second rounds. Even the third and fourth rounds contain 3.6 to 3.9 radial inches of white sapwood : sufficient to produce second and third quality clefts.

(ii) *By visual observation.* The trees were graded by the buyer and feller as they were being cut. Trees from the east side of the Plantation, the area most seriously attacked by *Armillaria*, were thought capable of producing only second and third quality clefts. Of these, 6 trees giving 17 rounds were badly affected : 3 rounds were rejected as worthless, and the others severely down-graded to third, fourth or boys'.

The trees from the west side of the Plantation were judged of good quality. They produced 4 rounds each and over 5 radial inches of white sapwood in the basal round. In the lower rounds, stain was slight, pale brown in colour and more or less concentric. The upper rounds showed pale straw coloured heartwood with a regular amount of outside white sapwood. Though the third round often contained a small (3-4 in. diameter) branch wound, a fourth round was obtained from the timber above. When cross cut, it was found that the stain was restricted to the wood of the branch : little had spread into the parent timber.

The Avenue trees (12-23) were considered excellent for their size ; they contained a minimum of heartwood and over $5\frac{1}{2}$ radial inches of white sapwood in both rounds.

The Line trees (6-11) were large. Their basal rounds contained over 5 radial inches of white sapwood, but the ratio of heartwood to white sapwood was high (1.07:1.0 compared with 0.78:1.0 and 0.92:1.0 for the Avenue and Plantation trees respectively). It was also found that very large trees do not necessarily contain more white sapwood. In tree No. 11 (B.H.G. = 78.5 in.) the 4 rounds contained means of only 5.0, 4.0, 4.0, 4.0 inches of sapwood compared with 22.0, 16.0, 16.0, 16.0 inches of heartwood.

Relation between estimated and true quality.

An opportunity to relate the buyers' estimate of quality with that recognized in the factory was afforded during the processing of the five trees sold in 1956. These trees were large (B.H.G. 63.7 in.) and produced 21 rounds. The buyer, noting the existence of horizontal cross cracks in the bark about 4 in. long, forecast that bar stain would be present and the timber of low value ; he believed that the slow growth of the trees, judged by the small amount of inner bark showing, would make them suitable only for boys' bats.

On the other hand, when felling the trees the contractor classed them as above average. The basal cut showed a small irregular yellow-orange stained zone extending from the periphery of the heartwood as radial projections into the sapwood (Figs. 8 and 11). The intermediate and terminal cuts showed only heartwood coloration (Fig. 7).

The true quality of these trees was indicated when tree No. 3 (B.H.G. 62 in.) was cleft at the factory. Clefts with a tangential edge of 5 in. were made by splitting the rounds radially with a small axe and then driving in an ash wedge ; the bark was then scraped off, and the rough clefts trued up by circular saw. Fig. 8 shows the dimensions of white sapwood, rough and trued cleft. The art

of clefting is to decide which side of the cleft shall become the face of the bat, and which end the top ; seemingly poor rough clefts can be upgraded by skilful conversion. Clefts were trued to $4\frac{7}{8}$ in. which, with shrinkage in seasoning and wastage in conversion, allows $4\frac{1}{4}$ in. for the finished bat blade.

In the basal round of this tree the white sapwood averaged 5 in. in width and the use of this criterion to forecast the quality of the clefts was justified by the results obtained. The round gave 13 rough clefts, all of which were judged first quality. When trued up, they were graded as follows :

- | | |
|--|------------|
| 3 — pure white, without blemish or heartwood | Quality I |
| 7 — without blemish, but with the heartwood
running into the bat face at one end to about
1 in. | Quality I |
| 3 — without blemish, but with a 2 in. band of
heartwood extending along the length of the
bat face | Quality II |

Figs. 13 and 12 show a first quality cleft, and the central heartwood zone of this round. Pin knots, forming slight distortion in the grain, were present, but they did not affect the grading of the clefts. The width of white sapwood decreased with height, and the slow growth of the trees was shown by the narrowness of the annual rings. The set was $1\frac{1}{2}$ in. to 2 in. in diameter and was closely adherent to the timber when cleft ; it had large branch wounds, over 1 in. in diameter, which had healed over (Fig. 12). The distortion of the grain was clearly visible to within a radial distance of $1\frac{1}{2}$ in. from the wounds. Despite these injuries the wood was excellent, with no suggestion of bar stain.

For comparison some trees from a valley in the Cotswolds were cleft at the same time. These had been judged of high quality by the buyer. They were 15 years old, quick grown, of certified stock, and had been well tended throughout their life. Their external appearance was very good ; no horizontal cross cracks were present in the bark ; the sets had been specially raised (4) and fell away readily when the trees were cleft.

Although the side branch wounds in the set were less than $\frac{1}{4}$ in. in diameter, the whole of the timber was stained yellow-orange ; ray projections reached to within 1 in. or 2 in. of the bark on the cross-cut face, and in longitudinal section the association of bar stain with small branch wounds in the set, and a slight thickness of the bark, could easily be seen (Fig. 14). Though the even growth and straight grain resulting from their careful cultivation had ensured that losses in conversion would be a minimum, the quality was disappointing.

It is therefore clear that the relationship between wounds and bar stain is not simple and that visual estimates of quality can be misleading. It is worthy of note that whereas the Long Ashton trees were grown on a dry site from 4 year-old sets of $1\frac{1}{2}$ –2 in. diameter, the Cotswold trees had been grown on a very wet, though not stagnant, river site from 2 year-old sets of $\frac{1}{2}$ –1 in. diameter. The water relations of the site appear to be an important factor in determining the occurrence of stain.

Basket Wood.

Willow veneer is used in conjunction with poplar veneer for making chip baskets etc. ; it is tougher than poplar and is preferred for the handles and corners of the containers, but the amount required is small in relation to the

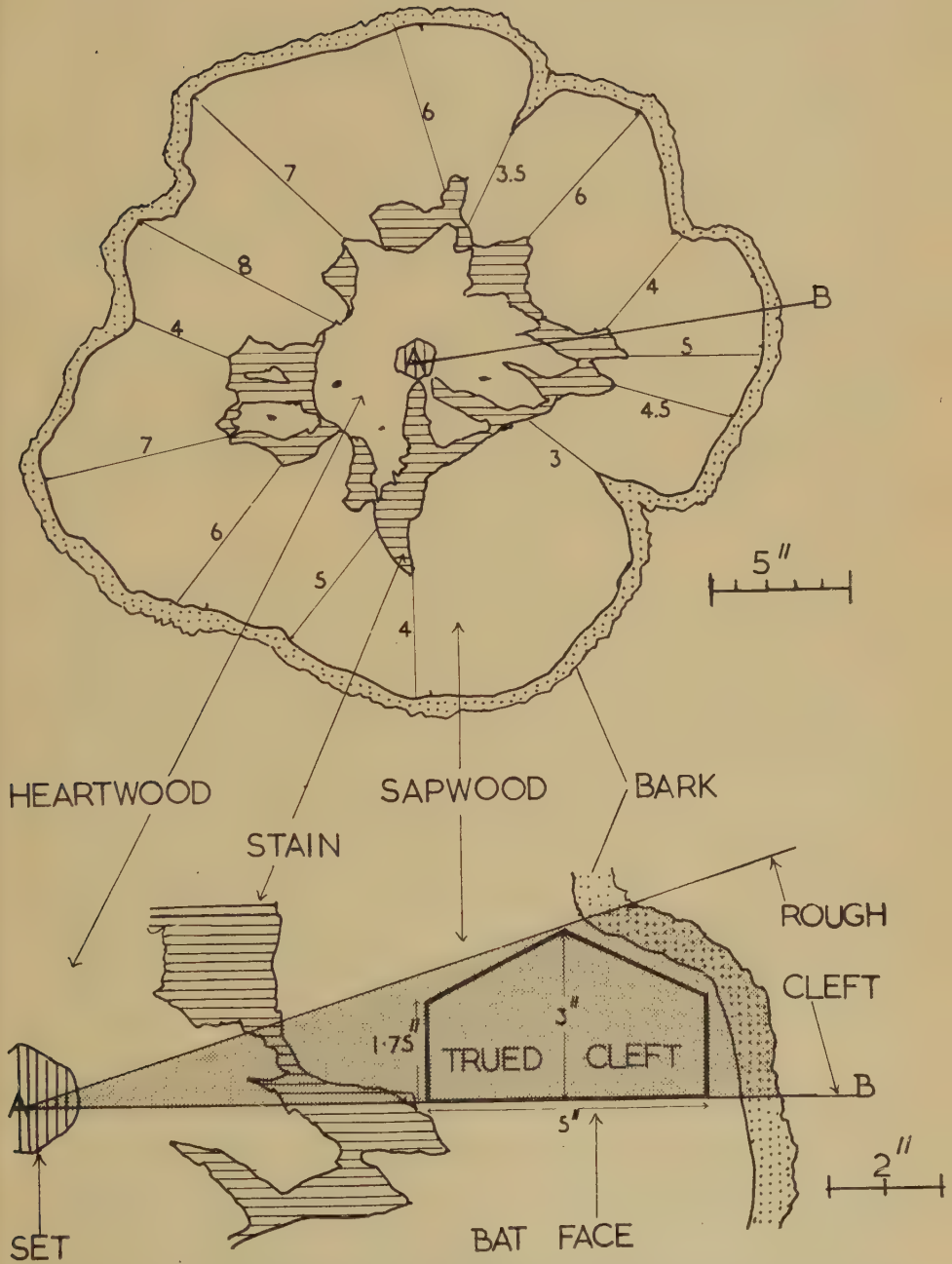


Fig. 8. Above. Cross cut face of Tree No. 5, showing width of sapwood in inches.
Below. Section A B, showing relation between width of sapwood, rough cleft and trued cleft.

quantity of poplar used. The veneer is turned from straight poles of uniform length that must be over 8 in. quarter girth (QG) and free from large branch wounds and knots (Fig. 5). During the war willow was used in matchmaking, for which it is almost as suitable as poplar. Both these markets could be expanded if regular supplies of more even quality could be ensured.

Basket wood was taken from 46 trees (Nos. 12-57) in 7 ft. lengths for convenience of transport. All but two trees contained at least one piece (Table I) but most of the 106 pieces came from trees in the west of the Plantation where competition for light had caused the pollard stems to grow long and straight without side branches. 12 pieces from the more branched Avenue trees were rejected, leaving 94 pieces ranging from 8 in. to 10 in. QG. The volume of a piece 8 in. QG and 7 ft. long is 3.11 Hoppus feet and a volume exceeding 292 Hoppus feet was thus extracted.

It was classed by the mill as "quite satisfactory" and valued at £65 16s. 0d. delivered, equivalent to 14s. 0d. per piece or 4s. 8d. per cube; this compares with 10s. 0d. per piece and 3s. 0d. per cube valued on the site by a contractor.

Some basket wood of varying lengths and thickness, with occasional large branch wounds, was obtained from trees Nos. 6-11. It was accepted locally for £4 10s. 0d. delivered, or 2s. 6d. per cube.

Pulpwood.

The Pulp Mill issues specifications for the material required: the logs must be over 3½ in. minimum diameter, straight and delivered in parcels of uniform length (Fig. 6). Six trees (Nos. 6-11) gave 251 pieces weighing 3 tons; of these 150 were over 5 in. in diameter. The quality was described as good, being straight, free from disease, and without branch snags. It realized £4 7s. 6d. per ton delivered, a bonus of 10s. 0d. per ton over the basic price, paid partly for quality and partly because the journey to the mill exceeded 75 miles.

Firewood.

The tops of 46 trees (Nos. 12-57) were sold to a local timber merchant, who extracted the branch wood down to 2½ in. diameter, obtaining 11 medium sized loads of timber; about 1 cord per tree. For this he paid £17 5s. 0d. or 7s. 6d. per tree. Since he had previously quoted 17s. 0d. per tree for converting the tops into firewood, this material must have been worth 24s. 6d. per tree; in all £67 17s. 0d.

Methods and Costs of Conversion.

Cricket Bat Rounds and Basket Wood.

The usual felling methods, employing axe and saw, cannot be used because the strain imposed splits the timber. The root spurs are first exposed, and then axed away at ground level, leaving the bole as nearly cylindrical as possible. The first saw cut is made as low as possible on the side to which it is intended the tree shall fall. The second cut is then made from the opposite side, at a slightly higher level; as the first cut is approached, the tree leans over to close it (Fig. 3). The remaining wood is cut very carefully by swivelling the saw sideways, cutting completely through the valuable outer wood first and leaving the core till last. Power driven chain saws have now largely replaced

manual saws ; wedges may be necessary as the saw cut nears the centre of the tree. Despite their size cricket bat trees are light and rarely do much damage in falling, but for the same reason it is unwise to attempt to fell when winds are high. If when the tree falls a piece of outer timber is still uncut, it splits right up the bole and much valuable timber is lost. An experienced woodman and inexperienced assistant felled the Long Ashton trees without incident. When felled the trees were easily cross cut by power saw into rounds and basket wood. Often wedges were required, but both jobs could be undertaken by one man with occasional assistance (Fig. 4). Sometimes difficulties were experienced in cross cutting the basket wood because of the need to work in a confined space.

Usually bat trees are sold to merchants who fell, transport the rounds, cleft them, and sell the graded seasoned clefts to the bat manufacturers. The Long Ashton trees (Nos. 6-57) were sold direct to the bat manufacturers for £450 with an additional allowance of £60 or 23s. 0d. per tree to cover the cost of felling and loading by a local contractor. Because of the size of the trees this was 3s. 0d. per tree more than the usual price.

Estimates from two felling contractors were received. One quoted 15s. 6d. per tree, the other 18s. 3d. per tree : 10s. 0d. to fell and cross cut plus 8s. 3d. for hauling 3 rounds to the railway station. The lower offer, representing £40 for 52 trees, was accepted. The contractor anticipated one week's work and agreed also to cut and stack the tops of 46 trees for firewood, taking in payment the basket wood present in the trees. Though he estimated this at only 35 pieces he obtained 94 pieces, valued at £65 16s. 0d., but was prevented by lack of time from converting more than 11 small trees for firewood. This work took the contractor and assistant 10 full working days. It took them about $\frac{1}{4}$ -hour to prepare and fell a tree, about 10 minutes for one man, with occasional assistance, to cross cut it into 3 rounds, and about 1 hour per man per tree to obtain the basket wood ; in all about one hour for two men per tree.

Using a tractor and trailer the rounds and basket wood from the plantation were hauled $\frac{1}{4}$ mile, and then stacked alongside a hard road, by three men in 11 hours. The rounds were loaded into a 3 ton lorry, taken 3 miles to the station and unloaded into railway trucks. Three journeys were required, taking two men a total of 18 man hours. The rounds weighed 12 tons $2\frac{1}{2}$ cwt. and filled $2\frac{1}{2}$ open wagons 18 ft. in length and of 10 tons capacity. For loads in excess of 4 tons, carried 200 miles, the railway rate is £4 per ton. The cost of rail transport was thus £48 10s. 0d., i.e. 18s. 8d. per tree or 6s. 3d. per round. For comparison the road charge would have been £121 0s. 0d. delivered to the works yard.

Pulpwood and Basketwood.

The tops of six trees were cross cut with a small power saw into basketwood by one man working alone. The small material over $3\frac{1}{2}$ in. diameter was then cross cut into 4ft. lengths for pulpwood, and all side branches trimmed off flush with the bark, leaving no branch snags. Prices of 17s. 0d. and 10s. 0d. per tree were quoted for the conversion ; the lower figure was accepted. Conversion took 21 man hours and the operator stated that £3 or 3s. 0d. per hour was insufficient for a skilled operator accustomed to piece rates ; £5 for 6 trees would have been a more realistic figure. The pulpwood was hauled $\frac{1}{2}$ mile to a hard road and loaded on a 4 ton lorry by 4 men in $1\frac{1}{2}$ hours at a cost of about £4.

The 75 mile journey to the mill took most of a day and was costed at £7 10s. 0d. for lorry and driver, giving a total cost of £14 10s. 0d.

35 Hoppus feet of basketwood were loaded and delivered 10 miles at a cost of £1.

Firewood.

After the rounds and basketwood had been extracted from the remaining 46 trees one man trimmed out all the useful material over 2½ in. in diameter using an axe and a small power saw. He piled all the brushwood and left the site very tidy, taking 51 hours to trim 40 trees. With the help of a mobile hoist 11 medium sized lorry loads of firewood were extracted.

For this he paid 7s. 6d. per tree. Offers made by other contractors show the variable value of firewood. They were : (i) to fell, cross cut and transport the rounds, in return for the firewood and a charge of 5s. 0d. per tree : (ii) to trim out and stack the firewood ready for disposal by the Station, charging (a) 17s. 0d. per tree, (b) 12s. 6d.-15s.0d. per tree, (c) in return for one 7ft. piece of basketwood per tree. The last offer was accepted, but the contractor was unable to complete the work because he had seriously underestimated the size of the trees. The firewood was therefore sold to another contractor for 7s. 6d. per tree.

Discussion.

Total receipts and expenses have been summarized in Table III. Unfortunately a balance sheet for converting the tree tops can be given only for six trees, as the basketwood of the other forty-six trees felled in 1957 was exploited by the contractor.

TABLE III.
TOTAL RECEIPTS AND EXPENSES.

<i>Receipts. By :</i>	£	s.	d.	<i>Expenses. To :</i>	£	s.	d.
Sale of trees 1-5	60	0	0				
Sale of trees 6-57	450	0	0				
Felling allowance 6-57 ..	60	0	0	Felling trees 6-57	40	0	0
Firewood, trees 12-57 ..	17	5	0				
Pulpwood, trees 6-11 ..	13	2	6	Conversion, trees 6-11	3	0	0
Basketwood, trees 6-11 ..	4	10	0	Loading and transport pulpwood	11	10	0
				Loading and transport basketwood	1	0	0
Total Receipts	£604	17	6	Total Expenses	£55	10	0
				Balance (Profit)	549	7	6
				Total	£604	17	6

It will first be noticed that the price obtained for the bat timber is greater than that suggested in a recent bulletin of the Forestry Commission (5) in which a figure of £5 is quoted for a well-grown tree of 48-56 in. girth. Compared with £12 each for the trees sold in 1956, the trees sold in 1957 realized £8 8s. 0d. each. As ten of the trees were undersized and affected by *Armillaria*, this price was considered satisfactory.

PLATE VII.



Fig. 2. Plantation ; narrow-angled pollard stems. Trees 25-28 and 33 in foreground ;
bole branch-free to 9' 6"



Fig. 3. Felling tree No. 3 with power saw ; second cut.



Fig. 4. Cross cutting bole into cricket bat lengths with power saw and wedge.
(Tree No. 53.)

PLATE VIII.



Fig. 5. Rounds of cricket bat timber (in foreground and loaded on lorry) and 7ft. lengths of timber for basket wood veneer.



Fig. 6. 3 ton load of pulpwood in 4ft. lengths.

PLATE IX.



Fig. 9. Tree killed by *Armillaria*; fallen bark exposes white mycelium. (Tree No. 46).



Fig. 10. The same tree felled. Cross cut face shows the extent of the peripheral stain caused by the fungus.

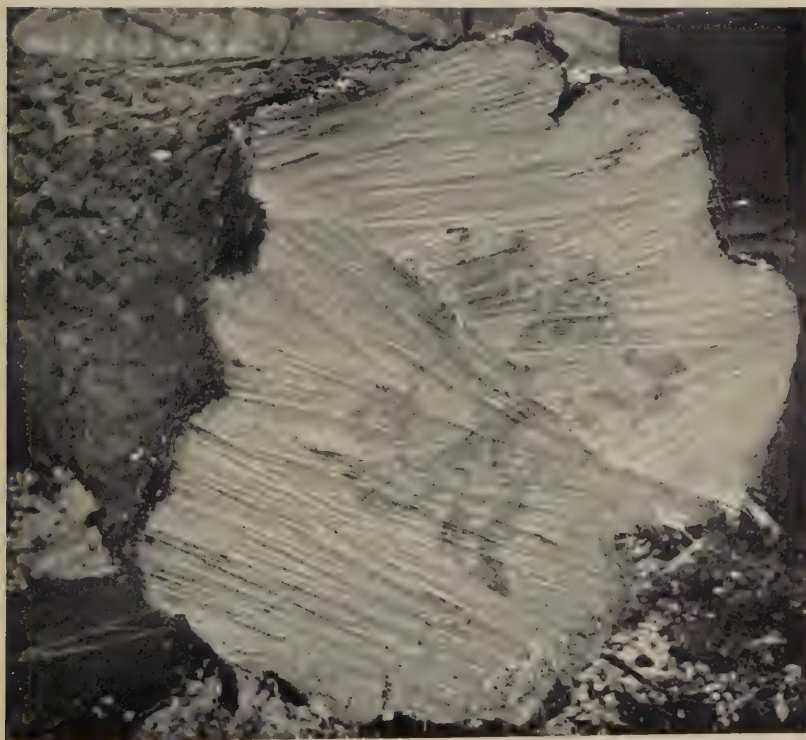


Fig. 11. Tree of good quality; small area of heartwood and only slight amount of stain. (Tree No. 5).

PLATE X.

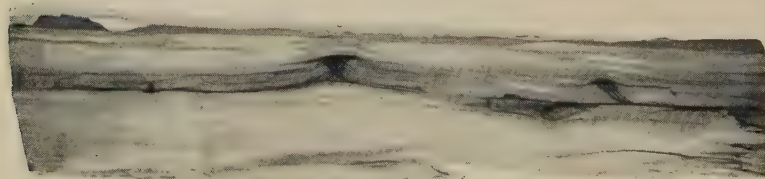


Fig. 12. Centre of tree No. 3 when cleft; large set with large branch wounds.



Fig. 13. 1st class cleft from tree No. 3; no stain despite large branch wounds.



Fig. 14. Round from Cotswolds cleft in two, showing bar stain, trapped bark and small set.

All the trees were sold direct to the bat maker rather than through bat merchants. Though this may seem entirely advantageous, it should be remembered that the merchants are long established and have a unique knowledge of the relation between the tree's external appearance and the quality of its timber. While their forecast of the relative qualities of the Cotswold and Long Ashton trees was incorrect their assessment was based on published criteria (1, 5, 6, 7, 8, 9). Further investigation is needed of the effect of soil moisture and size of set on damage caused by stain and wounds.

Of the uses to which the branchwood can be put, the most profitable would appear to be basketwood at 4s. 8d. per cube delivered. But for the initiative of the contractor, who received material valued at £47 on the site, this timber would have been included in that sold for firewood.

There was a loss of £1 7s. 6d. on the experimental load of pulpwood. Conversion costs were low, but loading and transport costs were high. Though willow is very acceptable to the pulp makers, profits are not likely to be more than marginal since purchase by weight penalizes a timber as light as willow.

Sales for firewood must be regarded as a means of ensuring that the site be left clean and tidy. Bat willow is not a good firewood and high prices cannot be expected. The material might have been more valuable for making stakes or rails but these markets are not readily accessible.

Acknowledgments.

I wish to thank Professor H. G. H. Kearns for his interest and help, Mr. D. E. Aliband for assistance with the photographs, and the following for their generous co-operation: Messrs. Slazengers Ltd., Horbury, Yorks.; Sudbrook Pulp Mill Ltd., Chepstow, Mon.; The Bredon Package Co. Ltd., Evesham, Worcs.; Cheddar Valley Chip Baskets, Cheddar, Som.; W. Staddon, Esq., Clevedon, Som., and E. J. Clarke, Esq., Charney Bassett, Berks.

REFERENCES.

- (1) HUTCHINSON, H. P. (1939). The manuring of cricket bat willow trees. *Ann. Rep. Long Ashton Res. Sta. for 1938*, 249-253.
- (2) HUTCHINSON, H. P. (1931). The production of cricket bat timber. *Ann. Rep. Long Ashton Res. Sta. for 1930*, 215-219.
- (3) HUTCHINSON, H. P. (1932). The value of young bat willow trees. *Ann. Rep. Long Ashton Res. Sta. for 1931*, 185-186.
- (4) HUTCHINSON, H. P. (1938). The raising of sets of the cricket bat willow. *Ann. Rep. Long Ashton Res. Sta. for 1937*, 243-249.
- (5) FORESTRY COMMISSION (1958). Bull. No. 17. *Cultivation of the cricket bat willow*.
- (6) HUTCHINSON, H. P. (1934). The cultivation of *Salix alba* var. *caerulea*—the cricket bat willow. *Quart. J. Forestry*, **27**, 100-114.
- (7) HUTCHINSON, H. P. (1934). Defects in cricket bat willow timber. *Ann. Rep. Long Ashton Res. Sta. for 1933*, 180-185.
- (8) HUTCHINSON, H. P. (1937). The effects of removal and retention of the lateral branches in the production of sets of the cricket bat willow. *Ann. Rep. Long Ashton Res. Sta. for 1936*, 231-234.
- (9) HUTCHINSON, H. P. (1937). Dormant roots and buds of the cricket bat willow, *Salix alba* var. *caerulea* and their effects in the wood. *Ann. Rep. Long Ashton Res. Sta. for 1936*, 235-238.
- (10) METCALFE, G. (1939). Observations on the anatomy of the cricket bat willow (*Salix caerulea* Sm.) *New Phytol.*, **38**, 150-158.

METEOROLOGICAL RECORDS, 1957.

Month	AIR TEMPERATURE (F°.)							RAINFALL (")				SUNSHINE (hours)		SOIL TEMPERATURE at 09.00 G.M.T.		
	Means			Diff. from normal	Max.	Min.	No. of ground frosts	Total	Per cent. of average	Most in a day	Daily mean	Per cent. of average	4"	8"	24"	
	A Max.	B Min.	Means of A & B													
January	48.0	37.7	42.9	+ 2.5	57	28	16	3.20	95	0.85	1.27	81	40.5	41.2	43.2	
February	48.7	37.3	43.0	+ 2.3	54	27	17	3.46	134	1.05	2.81	116	40.9	41.9	44.3	
March	56.2	42.9	49.5	+ 5.6	64	29	9	2.86	123	0.58	2.91	75	47.0	47.1	47.2	
April	57.0	40.9	48.9	+ 1.3	66	32	11	0.14	6	0.08	5.25	96	49.3	48.8	48.5	
May	60.5	43.0	51.8	— 1.3	72	33	6	1.94	75	0.42	7.13	114	54.1	52.6	54.2	
June	71.7	50.6	61.1	+ 2.6	86	38	3	1.79	85	0.72	9.74	139	62.2	61.2	60.1	
July	69.0	55.6	62.3	+ 0.8	82	45	0	4.47	141	0.85	4.80	81	62.5	61.9	63.2	
August	68.1	53.3	60.7	— 0.3	79	43	0	3.15	87	0.80	5.27	89	61.4	60.8	63.3	
September	62.0	50.1	56.1	— 1.0	68	36	1	4.57	145	1.02	3.63	77	56.8	56.6	59.9	
October	59.5	49.5	52.7	+ 1.6	68	34	6	3.72	96	0.77	2.70	82	51.7	51.7	55.9	
November	48.3	38.0	43.1	— 1.7	55	27	12	2.76	75	1.12	2.04	108	42.2	43.8	49.7	
December	46.7	34.7	40.7	— 0.7	56	23	19	2.56	72	0.64	1.67	113	39.4	40.9	44.6	
Totals or Means	58.0	44.2	51.1	+ 1.0				34.62	95		4.10	98	50.7	50.7	52.8	

G. E. CLOTHIER.

PUBLICATIONS, 1957.

(Including those of the A.R.C. Unit of Plant Nutrition)

ABBOTT, D. L.

- (1) Temperature and the dormancy of apple seeds. *Proc. 14th int. hort. Congr.*, 746-753.
After-ripening is shown to be a reversible process; in partially after-ripened seeds dormancy can be re-imposed by subjection to warm temperatures. 17°C is a neutral compensation temperature at which the capacity of the seeds to germinate remains constant.

BEECH, F. W. & CARR, J. G.

- (2) The use of marginally punched cards as an aid to microbial classification. *Lab. Practice* 1957, 101-102.

BENNETT, S. H.

- (3) The behaviour of systemic insecticides applied to plants. *Ann. Rev. Ent.* **2**, 279-296.

BOULD, C.

- (4) Horticulture. *Rep. Progr. appl. Chem.* **41**, 525-534.
(5) Iron chelates in plant nutrition. *J. Sci. Fd Agric.* **8**, S1-S5.
(6) The effect of cover crops on young dessert apples. *The Grower, Fruit Review* **48**, 838-840.

BRADFIELD E. G.

- (7) An improved formaldoxime method for the determination of manganese in plant material. *Analyst* **82**, 254-257.
The method eliminates interference by iron, copper and phosphate.

BURROUGHS, L. F.

- (8) 1-Aminocyclopropane-1-carboxylic acid: a new amino-acid in perry pears and cider apples. *Nature* **179**, 360-361.
(9) The amino-acids of apple juices and ciders. *J. Sci. Fd Agric.* **8**, 122-131.

BYRDE, R. J. W.

- (10) The varietal resistance of fruits to brown rot: II. The nature of resistance in some varieties of cider apple. *J. hort. Sci.* **32**, 227.
Resistance of high-tannin cider varieties to brown rot appears to arise through the inactivation of fungal macerating enzymes by oxidized polyphenols in the injured tissue.

BYRDE, R. J. W. & WOODCOCK, D.

- (11) Fungal detoxication: 2. The metabolism of some phenoxy-*n*-alkylcarboxylic acids by *Aspergillus niger*. *Biochem J.* **65**, 683.
The fungus broke down the aliphatic side chains of these acids by β -oxidation, and also hydroxylated the aromatic nucleus in the *para*- and, to a lesser extent, the *ortho*-positions.

BYRDE, R. J. W. & WOODCOCK, D.

- (12) Effect of the interaction between chelating agents on their fungitoxicity. *Nature* **179**, 539.
The effect of added Cu^{2+} and ethylenediaminetetraacetic acid (disodium salt) on the fungistatic activity of 5-*n*-amyl and 5-phenyl-8-hydroxyquinoline is discussed.

CAMPBELL, A. I.

- (13) Killing the weeds that choke black currants. *The Grower* **48**, 1022-1023.

CAMPBELL, A. I. & LUCKWILL, L. C.

- (14) 2:4-DES can help a lot in fruit crops. *The Grower* **47**, 32-34.

CANDELA, M. I., FISHER, E. G. & HEWITT, E. J.

- (15) Molybdenum as a plant nutrient: X. Some factors affecting the activity of nitrate reductase in cauliflower plants grown with different nitrogen and molybdenum levels in sand culture. *Plant Physiol.* **32**, 280-288.

Nitrate reductase activity in cauliflower is dependent on nitrogen source as well as on molybdenum supply, and is induced by nitrate or nitrite. Activity is distributed unequally in plants and is maximal in mature but not senescent leaves. Light and air are required for the maintenance and synthesis of the enzyme in leaves.

CARR, J. G.

- (16) Occurrence and activity of some lactic acid bacteria from apple juices, ciders and perries. *J. Inst. Brewing* **63**, 436-440.

CARR, J. G., POLLARD, A., WHITING, G. C. & WILLIAMS, A. H.

- (17) The reduction of quinic acid to dihydroshikimic acid by certain lactic acid bacteria. *Biochem. J.* **66**, 283-285.

CORKE, A. T. K.

- (18) Apparatus for recording the rate of spore discharge. *Plant Pathology* **6**, 25.

CORKE, A. T. K. & MARSH, R. W.

- (19) Increasing the yield of black currants. *The Grower* **48**, 679.

CRANG, ALICE & STURDY, MARGARET.

- (20) *Domestic Preservation of Fruit & Vegetables* (Revised Edn.) M.A.F.F. Bull. No. 21, H.M.S.O., 108 pp.

DOWNING, D. F.

- (21) Synthesis of tectorigenin. *Handbook XVIth int. Congr. pure and appl. Chem., Paris*, 211.

GUNDRY, C. S.

- (22) The evolution of apple growing in England. *R.H.S. Fruit Year Book*, 1958, 89-103.

HEWITT, E. J.

- (23) Some aspects of micronutrient element metabolism in plants. *Nature* **180**, 1020.

HEWITT, E. J., AGARWALA, S. C. & WILLIAMS, A. H.

- (24) Molybdenum as a plant nutrient : VIII. The effects of different molybdenum and nitrogen supplies on the nitrogen fraction in cauliflower plants grown in sand culture. *J. hort. Sci.* **32**, 34-38.

HEWITT, E. J. & CANDELA, M. I.

- (25) Molybdenum as a plant nutrient : IX. The effects of different molybdenum and manganese supplies on the uptake and distribution of molybdenum in tomato plants grown in sand culture. *J. hort. Sci.* **32**, 149-161.

Increasing levels of manganese from deficient to toxic concentrations caused significantly increased contents of molybdenum in all parts of tomato plants in spite of the increased severity of molybdenum deficiency symptoms. It is concluded that manganese has a complex effect on molybdenum nutrition in tomato.

HILL-COTTINGHAM, D. G.

- (26) Spectrophotometric determination of iron chelates. Part II. *Analyst* **82**, 524-5.

Optimum conditions are described for the quantitative estimation of the iron chelates of HEEDDA, CDTA and EDHPA (Chel 138).

- (27) A spectrophotometric method of analysis of chelate solutions and its application to the study of iron chelates in soils and plants. *Soil Sci.* **84**, 43-49.

HILL-COTTINGHAM, D. G. & LLOYD-JONES, C. P.

- (28) Behaviour of iron chelates in calcareous soils : I. Laboratory experiments with Fe-EDTA and Fe-HEEDTA. *Plant and Soil* **8**, 263-274.

The chelates, labelled with ^{59}Fe , were applied to a highly calcareous Evesham clay. Extracts made at intervals up to fifteen days showed decreases in soluble iron attributable to sorption of chelate by the clay and to replacement of iron by calcium in the chelate molecule. Isotopic exchange of ^{59}Fe with soil iron was considerable.

HOBBS, E. W.

- (29) Pillar trees. *R.H.S. Fruit Year Book* 1958, 48-52.
(30) Soft fruits for the garden. *Amateur Gardening* **76**, 12.

KIESER, M. E., POLLARD, A. & TIMBERLAKE, C. F.

- (31) Metallic components of fruit juices : I. Copper as a factor affecting sedimentation in bottled apple juices. *J. Sci. Fd Agric.* **8**, 151-158.

LUCKWILL, L. C.

- (32) The chemical thinning of apples in Britain. *Agric. Rev.* **3**, 19-22.

LUCKWILL, L. C.

- (33) Studies of fruit development in relation to plant hormones : IV. Acidic auxins and growth inhibitors in leaves and fruits of the apple. *J. hort. Sci.* **32**, 18–33.
Apple leaves and fruits are shown to contain three acidic growth-promoting and two acidic growth-inhibiting substances. The distribution of these substances in leaves, fruits and seeds of various ages is described and the possible significance of certain of these substances in fruit development is discussed.
- (34) Hormonal aspects of fruit development in higher plants. *Symposia Soc. exp. Biol.* : XI. *The Biological Action of Growth Substances*, 63–85.
- (35) Some impressions of fruit growing in Poland. *R.H.S. Fruit Year Book*, 1958, 104–108.
- (36) Herbicides. *Rep. Progr. appl. Chem.* **40**, 676–680.

MARSH, R. W.

- (37) Report to the Government of Yugoslavia on proposals for the expansion of the plant protection service. *United Nations Food and Agriculture Organization Rep. no. 625* : Rome, 1957.

MARSH, R. W., MONTGOMERY, H. B. S. & EDNEY, K. L.

- (38) Experiments in orchard spraying for the control of *Gloeosporium* rots of apples. *Plant Pathology* **6**, 39.
A programme of two late-summer sprays with 0.1% captan consistently gave a marked reduction in *Gloeosporium* attack on the stored crop.

MARTIN, J. T.

- (39) The mechanism of toxicity of insecticides and fungicides. *Plant Protection Conference*, 1956. Butterworths Sci. Publ., 1956, 104–112.
A discussion of factors influencing the deposition and efficiency of spray materials.

MARTIN, J. T., BATT, R. F. & BURCHILL, R. T.

- (40) Fungistatic properties of apple leaf wax. *Nature* **180**, 796–797.
Worcester and Cox leaf waxes were fractionated and the components tested for their ability to inhibit the germination of apple mildew conidia. The activity of the phenolic components is shown.

MARTIN, J. T. & SOMERS, E.

- (41) Solubilization of copper by leaves and water-soluble acids from leaf wax. *Nature* **180**, 797–798.
A contribution by the host plant to the toxic action of Burgundy mixture is suggested.

NICHOLAS, D. J. D.

- (42) Role of metals in enzymes with special reference to flavoproteins. *Nature* **179**, 800–804.
- (43) Effect of molybdenum deficiency on the catalase and peroxidase content of *Neurospora crassa*. *J. gen. Microbiol.* **17**, 689–698.
- (44) Role of trace metals in the nitrogen metabolism of plants with special reference to micro-organisms. *J. Sci. Fd Agric.* **8**, S 15–S 25.
- (45) The function of trace elements in the nitrogen metabolism of plants. *Ann. Bot.* **21**, 587–598.

NICHOLAS, D. J. D. & MEDINA, ANTONIA.

- (46) A zinc-dependent hexokinase from *Neurospora*. *Nature* **179**, 87–88.
- (47) Some properties of a Zn-dependent hexokinase from *Neurospora crassa*. *Biochem. J.* **66**, 573–578.
- (48) Interference by reduced pyridine nucleotides in the diazotization of nitrite. *Biochim. biophys. Acta* **23**, 440–442.
- (49) Hyponitrite reductase in *Neurospora*. *Nature* **179**, 533–534.
- (50) Metallo-enzymes in the reduction of nitrite to ammonia in *Neurospora*. *Biochim. biophys. Acta* **25**, 138–141.

NICHOLAS, D. J. D. & COMMISSIONG, K.

- (51) Effects of molybdenum and copper on some enzymes in *Neurospora*. *Nature* **180**, 555–556.
- (52) Effects of molybdenum and copper on some enzymes in *Neurospora*. *J. gen. Microbiol.* **17**, 699–707.

NICHOLAS, D. J. D., LLOYD-JONES, C. P. & FISHER, D. J.

- (53) Some problems associated with determining iron in plants. *Plant & Soil* **8**, 367-377.
⁵⁹Fe was used to show contamination of the foliage of glasshouse tomatoes by iron deposited as dust and to test procedures for its removal prior to leaf analysis.

POLLARD, A. & BEECH, F. W.

- (54) *Cider-making*: Rupert Hart-Davis, London, 1957, 94 pp.

RAKE, BARBARA A.

- (55) The history of gooseberries in England. *R.H.S. Fruit Year Book*, 1958, 84-87.
 (56) The development of adventitious roots on hardwood cuttings of gooseberries. *J. hort. Sci.* **32**, 195-198.

SOMERS, E.

- (57) Studies of spray deposits: III. Factors influencing the level of run-off deposits of copper fungicides. *J. Sci. Fd Agric.* **8**, 520-526.
 Representative wetting agents of non-ionic and cationic type lowered the level of "run-off" deposit only slightly, but with an anionic surface-active agent an exceptional reduction in deposit was achieved at concentrations greater than the critical concentration for micelle formation. In the absence of supplements spray retention increased with increasing wettability of the surface.
 (58) Modifications in the method of determining copper with bis-cyclo-hexanone oxalyldi-hydrazone. *Chem. & Ind.*, 1068.

SOMERS, E. & GARRAWAY, J. L.

- (59) Modifications in the method of determining copper with bis-cyclo-hexanone oxalyldi-hydrazone. *Chem. & Ind.*, 395.

SOMERS, E. & RICHMOND, D. V.

- (60) Sorption of copper from Burgundy mixture by leaves. *Nature* **180**, 798-799.
 A significant amount of copper was adsorbed by leaves and rendered non-fungicidal.

STEVENS, H. M.

- (61) The paper chromatography of some manganese and copper valency states. *Anal. Chim. Acta* **16**, 435-438.
 (62) The use of paper chromatography in the separation of the valency states of biologically important metals. *J. Sci. Fd Agric.* **8**, S38-S43.

STOTT, K. G.

- (63) The cultivation of willows for basket-making. *J. Forestry Commission* **25**, 142-143.

STURDY, MARGARET.

- (64) Bottling, canning and freezing fruits and vegetables. *Inst. Management Ass. J.*, 1957, 134-137.

THOMAS, W. D. E.

- (65) An introduction to work on radioactive tracers. *Sci. Hort.* **12**, 104-109.

TIMBERLAKE, C. F.

- (66) Metallic components of fruit juices: II. The nature of some copper complexes in apple juice. *J. Sci. Fd Agric.* **8**, 159-168.
 (67) The complexing of copper with natural components of fruit. *J. Sci. Fd Agric.* **8**, S66-S71.
 (68) A potentiometric and polarographic study of copper-catechol complexes. *J. chem. Soc.*, 4987-4993.

WALLACE, T.

- (69) Trace elements in plant nutrition, with special reference to crops. Fernhurst Lecture. *J. R. Soc. Arts* **105**, 5004.
 (70) Chlorine—an essential nutrient element. *The Grower* **47**, 933-4.

WHITING, G. C.

- (71) Occurrence of shikimic acid in gooseberry fruits. *Nature* **179**, 531.

WHITING, G. C. & CARR, J. G.

- (72) Chlorogenic acid metabolism in cider fermentation. *Nature* **180**, 1479.

WILLIAMS, A. H.

(73) The simpler phenolic substances of plants. *J. Sci. Fd Agric.* **8**, 385-389.

(74) The application of chromatography to nutritional problems in plants. *J. Sci. Fd Agric.* **8**, S33-S37.

An investigation of the simpler organic compounds of certain plants and their variations with changes in nutritional status.

WILLIAMS, R. R.

(75) The perry pear—a neglected fruit. *R.H.S. Fruit Year Book*, 1958, 78-83.

WILLIAMS, R. R. & CAMPBELL, A. I.

(76) Rosetting : growing problem with pears. *The Grower* **47**, 1521-1522.

WOODCOCK, D. & CLIFFORD, D. R.

(77) Synthesis of 3-nitro-2-naphthol. *J. chem. Soc.*, 4139-4141.

The hitherto unknown 3-nitro-2-naphthol, required in connection with work on plant growth-regulating substances, was synthesised and its identity established unambiguously.

TITLES OF PAPERS IN THE LONG ASHTON ANNUAL REPORTS

1953-1957

Author and Subject Indexes to the titles of all papers appearing in the Annual Reports from 1907 to 1952 were published with the Annual Report for 1952.

The same method of presentation is followed in this supplementary Index for 1953-1957. Publications are listed chronologically under authors and subjects. The date given is that on the title page of the Report in which the paper appears: the date of publication is one year later.

Author Index, 1953-1957

	Year	Page
ABBOTT, D. L.		
2:4:5-TP as a fruit ripening agent: I. Apple <i>var.</i> Worcester Pearmain	1953	53
Growth substances as fruit-thinning agents for apples. Progress report	1953	58
2:4:5-TP as a fruit ripening agent: II. Apple <i>var.</i> Worcester Pearmain	1954	47
Growth substances as fruit-thinning agents for apples. Progress report	1955	58
Growth substances as fruit-thinning agents for apples. Progress report	1956	57
ANON.		
A revised list of recommended varieties of cider apples	1956	44
BAKER, E. A.		
(See SKERRETT and BAKER)	1956	130
BATT, R. F.		
(See MARTIN and BATT)	1955	106
— and MARTIN. Spray application problems: XXXIII. The micro-determination of DDT	1956	127
(See KRENTOS, BATT and MARTIN)	1956	122
(See MAPOTHER and BATT)	1956	141
(See MARTIN, BATT and ROBERTS)	1957	84
BEECH, F. W.		
— and POLLARD. Problems of microbiological control in cider-making	1953	171
The production of bottled ciders free from deposit	1954	179
— and POLLARD. Acid changes in cider fermentations: I. The significance of acid changes in cider-making	1955	159
— BURROUGHS and WHITING. Acid changes in cider fermentations: III. The effect of sulphite treatments	1955	169
BENNETT, S. H.		
Spray application problems: VIII. The control of apple and plum aphides by DDT and BHC spring washes	1953	129
Spray application problems: IX. Observations on the time of application and influence of site of deposition of BHC on the control of apple sawfly (<i>Hoplocampa testudinea</i> Klug.)	1953	135
An unusual attack on apples by a sawfly (<i>Ametastegia</i> sp.)	1955	120
— and FURMIDGE. Spray application problems: XXIV. The study of plant surfaces and spray deposits by means of transparent impressions	1955	121
BOULD, C.		
The use of iron chelates for the control of lime-induced chlorosis in fruit. Progress report I	1953	91
— and BRADFIELD. A failure in apple trees on a strongly acid soil	1954	69
The use of iron chelates for the control of lime-induced chlorosis in fruit. Progress report II	1955	87
— and BRADFIELD. Foliar analysis in relation to black currant nutrition: I. Investigations on leaf disc sampling	1955	93

BOULD, C. (*contd.*)

	Year	Page
— and JARRETT. Cover crops in relation to soil fertility and tree nutrition : II. An experiment with dessert bush apple trees. Progress report I	1956	76
— and CATLOW. Manurial experiments with fruit : I. The effect of treatments on soil fertility and on the growth, yield and leaf nutrient status of strawberry, <i>var.</i> Royal Sovereign	1956	84
Soil conditioners : II. The effect of HPAN and VAMA on the yield of strawberries	1957	71

BRADFIELD, E. G.

(See BOULD and BRADFIELD)	1954	69
(See BOULD and BRADFIELD)	1955	93

BURCHILL, R. T.

Observations on the mode of perennation of apple mildew	1957	114
---	------	-----

BURROUGHS, L. F.

— and MAY. The composition of the juices of some varieties of cider apples	1953	178
— and POLLARD. The role of nitrogen and vitamin B ₁ in cider making. The production of cider fruit on bush trees. Vintage quality trials. Concluding report	1953	184
(See BEECH, BURROUGHS and WHITING)	1954	173
(See BEECH, BURROUGHS and WHITING)	1955	169
Acid changes in cider fermentations : IV. Yeast autolysis and cider stability	1955	174
— and CARR. The amino-acid content of cider in relation to the growth of lactic acid bacteria	1956	162

BUTT, D. J.

Spray application problems : XXVI. The range of fungicidal action of micro-deposits of captan on artificial surfaces and on leaves	1955	127
--	------	-----

BYRDE, R. J. W.

— and CORKE. The role of eradicant fungicides in the control of apple canker. II	1953	159
Observations on the sporulation of <i>Sclerotinia fructigena</i> on mummified apples and plums in late spring and summer	1953	163
— FIELDING and HARPER. Spraying experiments against apple and pear scab at Long Ashton, 1953	1953	167
(See COLES and BYRDE)	1953	109
(See COLES, MARTIN and BYRDE)	1954	74
— CLARKE and HARPER. Spraying experiments against apple scab at Long Ashton, 1954	1954	147
— and CORKE. The role of eradicant fungicides in the control of apple canker : III. A supplementary note	1954	162
— CLARKE and HARPER. Spraying experiments against apple scab at Long Ashton, 1955	1955	140
— CLARKE and HARPER. Spraying experiments against apple scab at Long Ashton, 1956	1956	103
(See COLES, MARTIN and BYRDE)	1956	101
— and WAUGH. Preliminary tests of potential orchard fungicides	1957	89
— CLARKE and HARPER. Spraying experiments against apple scab at Long Ashton, 1957	1957	93

CAMPBELL, A. I.

(See LUCKWILL and CAMPBELL)	1953	47
Rootstocks suitable for some new plum varieties raised at Long Ashton : nursery trials	1954	60
Stembuilders for cider trees : nursery trials	1955	46
(See WILLIAMS and CAMPBELL)	1956	51
Rootstocks and stembuilders for cider trees : nursery trial	1957	48
(See HOBBS and CAMPBELL)	1957	65
(See LUCKWILL and CAMPBELL)	1957	68

CANDELA, M. I.

(See HEWITT, FISHER and CANDELA)	1955	202
--	------	-----

CARR, J. G.

- and WHITING. Acid changes in cider fermentations. II. The effect of juice composition 1955 163
 (See BURROUGHS and CARR) 1956 162

CATLOW, E.

- (See HOBBS and CATLOW) 1955 61
 (See BOULD and CATLOW) 1956 84

CLARKE, G. M.

- and CORKE. Sources of variability in sampling black currants for leaf spot 1954 199
 (See BYRDE, CLARKE and HARPER) 1954 147
 (See BYRDE, CLARKE and HARPER) 1955 140
 — and CORKE. A rapid method of assessing black currant leaf spot 1955 196
 (See BYRDE, CLARKE and HARPER) 1956 103
 (See BYRDE, CLARKE and HARPER) 1957 93

CLOTHIER, G. E.

- Meteorological records, 1953 1953 208
 Meteorological records, 1954 1954 202
 Meteorological records, 1955 1955 201
 Meteorological records, 1956 1956 176
 Meteorological records, 1957 1957 156

COBBALD, T. E.

- Spray application problems : XLIV. A compressed air nozzle for small-volume spraying 1957 123
 Spray application problems : XLV. The performance of a power knapsack mist sprayer 1957 127

COLES, G. V.

- and BYRDE. The fungicidal properties of coal tar distillates. Progress report 1953 109
 — MARTIN and BYRDE. The fungicidal properties of coal tar distillates. Progress report II 1954 74
 — MARTIN and BYRDE. The fungistatic properties of coal tar constituents 1956 101

CORKE, A. T. K.

- Black currant leaf spot : I. Studies of perennation and infection .. 1953 154
 (See BYRDE and CORKE) 1953 159
 Bitter rot of apples : I. Branch inoculations with *Gloeosporium perennans* and *G. album* 1954 164
 (See BYRDE and CORKE) 1954 162
 (See CLARKE and CORKE) 1954 199
 (See CLARKE and CORKE) 1955 196
 Black currant leaf spot. A note on further laboratory tests of fungicides on overwintered leaves 1956 120

CRANG, B. ALICE

- and STURDY. A comparison of some varieties of fruit preserved by bottling and by freezing. Progress report IV 1953 199
 Notes on domestic meat and poultry preservation 1953 206
 — and STURDY. A comparison of some varieties of vegetables preserved by canning and by freezing. Progress report III .. 1954 187
 — and STURDY. A comparison of some varieties of fruit preserved by bottling and by freezing. Progress report V 1954 192
 — and STURDY. A comparison of some varieties of fruit preserved by bottling and by freezing. Progress report VI 1955 182
 (See STURDY and CRANG) 1955 188
 — and STURDY. A comparison of some varieties of vegetables preserved by canning and by freezing. Progress report IV .. 1955 178
 — — — A comparison of some varieties of vegetables preserved by canning and by freezing. Progress report V 1956 167
 — — — A comparison of some varieties of fruit preserved by bottling and by freezing. Progress report VII 1956 170
 (See STURDY and CRANG) 1957 137

EDNEY, K. L. (See MARSH and EDNEY)	1956	109
FIELDING, A. H. (See BYRDE, FIELDING and HARPER)	1953	167
FISHER, E. G. (See HEWITT, FISHER and CANDELA)	1955	202
FURMIDGE, C. G. L. Spray application problems : XVI. The evaluation of an average droplet diameter in sprays	1954	106
Spray application problems : XVII. The measurement of spray droplet size in the field	1954	118
(See BENNETT and FURMIDGE)	1955	121
GREENWOOD, M. Jubilee celebrations	1953	29
HARPER, C. W. (See BYRDE, FIELDING and HARPER)	1953	167
(See BYRDE, CLARKE and HARPER)	1954	147
(See BYRDE, CLARKE and HARPER)	1955	140
(See BYRDE, CLARKE and HARPER)	1956	103
(See BYRDE, CLARKE and HARPER)	1957	93
HEWITT, E. J. — and MCCREADY. The molybdenum requirements of tomato plants given different types of nitrogen supply in sand culture	1953	209
— FISHER and CANDELA. Factors affecting the activity of nitrate reductase in cauliflower plants	1955	202
The destruction of ascorbic acid by tissue preparations of cauliflower grown with different nitrogen and molybdenum supplies	1955	211
HISLOP, E. C. Some observations on the effects of fungicides on enzyme systems in <i>Botrytis cinerea</i>	1956	116
HOBBIS, E. W. — and MARSH. The infection of apple stems through wounds caused by geese	1953	89
— and CATLOW. A note on ten years' cropping of black currants at Long Ashton	1955	61
— and CAMPBELL. Leaf-bud propagation of a virus-tested loganberry clone	1957	65
JARRETT, R. M. (See BOULD and JARRETT)	1956	76
KEARNS, H. G. H. — and MORGAN. Spray application problems : X. The effects of spraying techniques on the control of some fruit insects. Lance and air-flow mist spraying	1953	139
— — — Spray application problems : XI. A note on the prepara- tion of a combined DDT- γ BHC emulsion of high wetting properties as a substitute for winter washes	1953	146
— MARSH and MORGAN. Spray application problems : XII. Further field experiments on the control of apple scab by small-volume sprays	1953	149
— MORGAN and WILKINS. Spray application problems : XVIII. Observations on the application of chlorbenside for the control of the winter eggs of the Red Spider mite (<i>Metatetranychus ulmi</i> Koch.)	1954	131
— MARSH and MORGAN. Spray application problems : XIX. Further field experiments on the control of apple scab by small-volume sprays	1954	137
— and MORGAN. Spray application problems : XX. Light-weight small power sprayers. (34 and 70 c.c. I.C. engines)	1954	138

KEARNS, H. G. H. (*contd.*)

— Small-volume air-flow spraying for the control of potato blight	1954	169
— MORGAN and WILKINS. Spray application problems : XXV. The application of chlorbenside and chlorfensone for the control of the winter eggs of the Red Spider mite (<i>Metatetranychus ulmi</i> Koch) ..	1955	125
— MARSH and MORGAN. Spray application problems : XXVII. Field experiments in the control of apple and pear scab by small-volume sprays, 1955	1955	136
— and MORGAN. Spray application problems : XXVIII. A compressed air spray nozzle for laboratory and field equipment for small-volume air-flow spraying	1955	146
— Spray application problems : XXIX. A tractor-driven air-flow mist-blower for experimental work	1955	151
— Spray application problems : XXX. Mobile observation platforms for the examination of tree crops	1955	156
— and MARTIN. Spray application problems : XXXV. The control of leaf-spot disease (<i>Mycosphaerella musciola</i>) on Lacatan bananas. The levels and distribution of Bordeaux mixture deposits ..	1956	135
— and MORGAN. Spray application problems : XXXVII. A disc punch for sampling leaves for the assay of spray deposits ..	1956	145
— Spray application problems : XXXVIII. A centrifugal spray pump (with an 80 c.c. 2-stroke engine)	1956	147
— Spray application problems : XXXIX. A general-purpose lance for use with power spray machinery on tropical crops. ..	1956	151
— Spray application problems : XL. A light-weight spray lance	1956	153
— Spray application problems : XLI. Modifications of the Long Ashton $\frac{1}{4}$ " B.S.P. spray nozzle for special requirements ..	1956	157

KIESER, MARGARET E.

— POLLARD, TIMBERLAKE and MOSELEY. Factors affecting the quality and stability of concentrated fruit juices : I. Black currant and apple concentrates	1953	189
(See LUCKWILL, KIESER and POLLARD)	1956	66
— POLLARD and SISSONS. The activity of pectin methylesterase in black currants : progress report	1957	134

KRENTOS, V. D.

— BATT and MARTIN. Spray application problems : XXXI. The determination of sulphur deposits on foliage	1956	122
--	------	-----

LLOYD-JONES, C. P.

Radioactive tracer studies during the period 1953-55	1955	116
--	------	-----

LUCKWILL, L. C.

Virus diseases of fruit trees : IV. Further observations on rubbery wood, chat-fruit and mosaic in apples	1953	40
— and CAMPBELL. The use of apomictic seedling rootstocks for apples. Progress report	1953	47
Virus diseases of fruit trees : V. Experiments on rubbery wood, mosaic and flat limb of apples	1955	51
(See TEAOTIA and LUCKWILL)	1955	64
Fruit drop in black currants : II. The effect of naphthalene acetic acid ..	1955	75
Fruit set on Cox's Orange Pippin in relation to spray programme ..	1956	61
— KIESER and POLLARD. Fruit drop in black currants : III. The effect of 1-naphthalene acetic acid applied before harvest	1956	66
Virus diseases of fruit trees : VI. Graft transmission of chat fruit ..	1957	56
— and CAMPBELL. The control of bindweed in black currants	1957	68

McCREADY, C. C.

(See HEWITT and McCREADY)	1953	209
-----------------------------------	------	-----

MAPOTHER, H. R.

— and BATT. Spray application problems : XXXVI. Benzene, toluene and naphtha formulations of spray washes	1956	141
---	------	-----

MARSH, R. W.

- (See KEARNS, MARSH and MORGAN) 1953 149
 (See KEARNS, MARSH and MORGAN) 1954 134
 A summary of apple scab control experiments at Long Ashton,
 1944-1954 1954 153
 (See KEARNS, MARSH and MORGAN) 1955 136
 — and EDNEY. Spraying trials at Long Ashton, 1953-56, for the
 control of *Gloeosporium* storage rot in Allington Pippins 1956 109

MARTIN, J. T.

- and BATT. Spray application problems : VII. The determination
 of DDT in plant materials 1953 121
 — and PICKARD. Spray application problems : XIII. Determination
 of captan deposits. Progress report 1954 83
 (See COLES, MARTIN and BYRDE) 1954 74
 (See MORGAN and MARTIN) 1954 97
 Spray application problems : XXI. The rapid assessment of deposits of
 copper fungicides 1955 98
 — and PICKARD. Spray application problems : XXII. Determination
 of captan deposits : II 1955 103
 — and BATT. Spray application problems : XXIII. Determination of
 deposits of DDT, *gamma*-BHC and chlorbenside 1955 106
 Studies on the natural protective covering of plants : I. Plant wax in
 relation to resistance to infection by fungi 1956 94
 Spray application problems : XXXII. Note on the determination of
 surface deposits of copper fungicides 1956 125
 (See COLES, MARTIN and BYRDE) 1956 101
 (See KRENTOS, BATT and MARTIN) 1956 122
 (See BATT and MARTIN) 1956 127
 (See KEARNS and MARTIN) 1956 135
 — and PICKARD. Spray application problems : XLII. Mercury
 deposits on apple fruits and foliage 1957 76
 — BATT and ROBERTS. Studies on the natural protective covering of
 plants : II. The wax and cutin of leaves and fruits 1957 84

MAY, YVONNE P.

- (See BURROUGHS and MAY) 1953 178

MORGAN, N. G.

- (See KEARNS and MORGAN) 1953 139
 (See KEARNS and MORGAN) 1953 146
 (See KEARNS, MARSH and MORGAN) 1953 149
 — and MARTIN. Spray application problems : XV. Copper and DDT
 deposits from large and small volume application 1954 97
 A prototype leaf-sampling disc cutter 1954 171
 (See KEARNS, MORGAN and WILKINS) 1954 131
 (See KEARNS, MARSH and MORGAN) 1954 134
 (See KEARNS and MORGAN) 1954 138
 (See KEARNS and MORGAN) 1954 169
 (See KEARNS, MORGAN and WILKINS) 1955 125
 (See KEARNS, MARSH and MORGAN) 1955 136
 (See KEARNS and MORGAN) 1955 146
 (See KEARNS and MORGAN) 1955 151
 (See KEARNS and MORGAN) 1955 156
 (See KEARNS and MORGAN) 1956 145
 (See KEARNS and MORGAN) 1956 147
 (See KEARNS and MORGAN) 1956 151
 (See KEARNS and MORGAN) 1956 153
 (See KEARNS and MORGAN) 1956 157

MOSELEY, MARY R.

- (See KIESER, POLLARD, TIMBERLAKE and MOSELEY) 1953 189

PICKARD, J. A.

- (See MARTIN and PICKARD) 1954 83
 (See MARTIN and PICKARD) 1955 103
 (See MARTIN and PICKARD) 1957 76

	Year	Page
PLANT, W.		
The growth of carrots on an acid soil	1954	203
POLLARD, A.		
(See BEECH and POLLARD)	1953	171
(See BURROUGHS and POLLARD)	1953	184
(See KIESER, POLLARD, TIMBERLAKE and MOSELEY)	1953	189
(See BEECH and POLLARD)	1955	159
(See LUCKWILL, KIESER and POLLARD)	1956	66
(See KIESER, POLLARD and SISSONS)	1957	134
RAKE, BARBARA A.		
The propagation of gooseberries : I. Some factors influencing the rooting of hardwood cuttings	1953	79
The propagation of gooseberries : II. The influence of basal wounding and size of shoot on the rooting of hardwood cuttings	1954	63
The propagation of gooseberries : III. The effect of time of taking and planting hardwood cuttings and the influence of buds on rooting	1955	78
The propagation of gooseberries : IV. Softwood cuttings	1956	70
The propagation of gooseberries : V. Layering	1956	72
The propagation of gooseberries : VI. The influence of source on the rooting of hardwood cuttings	1957	59
The classification of gooseberries : I. Useful characters for the classification and identification of varieties	1957	60
ROBERTS, MARGARET F.		
(See MARTIN, BATT and ROBERTS)	1957	84
SHARPLES, R. O.		
The reduction of orchard sources of <i>Gloeosporium</i> disease	1957	105
SISSONS, J. D.		
(See KIESER, POLLARD and SISSONS)	1957	134
SKERRETT, E. J.		
— and BAKER. Spray application problems : XXXIV. The determination of spray deposits of chlorobenzilate	1956	130
SOMERS, E.		
Spray application problems : XIV. Laboratory and field experiments with Burgundy mixtures	1954	90
The role of supplements in copper fungicide sprays	1955	111
Spray application problems : XLIII. Note on the preparation of Bordeaux mixture	1957	82
STOTT, K. G.		
Cricket bat willows. Sale and utilization of the Long Ashton trees	1957	143
STURDY, MARGARET		
(See CRANG and STURDY)	1953	199
(See CRANG and STURDY)	1954	187
(See CRANG and STURDY)	1954	192
(See CRANG and STURDY)	1955	178
(See CRANG and STURDY)	1955	182
— and CRANG. Domestic freezing of pork and pork products	1955	188
(See CRANG and STURDY)	1956	167
(See CRANG and STURDY)	1956	170
— and CRANG. Storage of frozen bacon, brawn and venison	1957	137
TEAOTIA, S. S.		
— and LUCKWILL. Fruit drop in black currants : I. Factors affecting "running-off"	1955	64
THOMAS, W. D. E.		
Application of the radio-active tracer technique to problems in plant nutrition and crop protection	1953	102

	Year	Page
TIMBERLAKE, C. F. (See KIESER, POLLARD, TIMBERLAKE and MOSELEY)	1953	189
WAUGH, NORA M. (See BYRDE and WAUGH)	1957	89
WHEATLEY, D. A preliminary comparison of the temperature-germination relationships of ascospores and of conidia of the apple and pear scab fungi (<i>Venturia inaequalis</i> and <i>V. pirina</i>)	1957	97
WHITING, G. C. (See CARR and WHITING) (See BEECH, BURROUGHS and WHITING)	1955 1955	163 169
WILKINS, A. H. (See KEARNS, MORGAN and WILKINS) (See KEARNS, MORGAN and WILKINS)	1954 1955	131 125
WILLIAMS, R. R. A survey of perry pears in the West Midlands: I. North-west Gloucestershire Perry pears and their characters: I The production of cider fruit on bush trees. Observations on yields and orchard behaviour, 1950-53. Final report Pollination requirements of cider apple varieties: II. Progress report, 1954 Perry pears and their characters: II. Perry pears for planting — and CAMPBELL. Rosetting and incompatibility of pears on Quince A. Progress report I	1953 1953 1954 1954 1954 1954 1956 1956	64 70 30 38 52 48 51
WILSON, D. Male sterility in Bristol Cross pear	1957	52
WOODCOCK, D. The effect of chemical structure on biological activity. The significance of chlorine in certain insecticides, fungicides, and plant growth- regulators	1953	96

Subject Index, 1953-1957

	Year	Page
ANALYTICAL METHODS		
Spray application problems : VII. The determination of DDT in plant materials. J. T. MARTIN and R. F. BATT	1953	121
The fungicidal properties of coal tar distillates. Progress report II. G. V. COLES, J. T. MARTIN and R. J. W. BYRDE	1954	74
Spray application problems : XIII. Determination of captan deposits. Progress report. J. T. MARTIN and J. A. PICKARD	1954	83
Spray application problems : XXI. The rapid assessment of deposits of copper fungicides. J. T. MARTIN	1955	98
Spray application problems : XXII. Determination of captan deposits : II. J. T. MARTIN and J. A. PICKARD	1955	103
Spray application problems : XXIII. Determination of deposits of DDT, gamma-BHC and chlorbenside. J. T. MARTIN and R. F. BATT	1955	106
Spray application problems : XXXI. The determination of sulphur deposits on foliage. V. D. KRENTOS, R. F. BATT and J. T. MARTIN	1956	122
Spray application problems : XXXII. Note on the determination of surface deposits of copper fungicides. J. T. MARTIN	1956	125
Spray application problems : XXXIII. The micro-determination of DDT. R. F. BATT and J. T. MARTIN	1956	127
Spray application problems : XXXIV. The determination of spray deposits of chlorobenzilate. E. J. SKERRETT and E. A. BAKER	1956	130
Spray application problems : XLII. Mercury deposits on apple fruits and foliage. J. T. MARTIN and J. A. PICKARD	1957	76
APPARATUS		
A prototype leaf-sampling disc cutter. N. G. MORGAN	1954	171
Spray application problems : XXXVII. A disc punch for sampling leaves for the assay of spray deposits. H. G. H. KEARNS and N. G. MORGAN	1956	145
APPLES		
<i>(and see Diseases and Pests, Apples).</i>		
The use of apomictic seedling rootstocks for apples. Progress report. L. C. LUCKWILL and A. I. CAMPBELL	1953	47
2:4:5-TP as a fruit-ripening agent : I. Apple <i>var.</i> Worcester Pearmain. D. L. ABBOTT	1953	53
Growth substances as fruit-thinning agents for apples. Progress report. D. L. ABBOTT	1953	58
2:4:5-TP as a fruit-ripening agent : II. Apple <i>var.</i> Worcester Pearmain. D. L. ABBOTT	1954	47
A failure in apple trees on a strongly acid soil. C. BOULD and E. G. BRADFIELD	1954	69
Growth substances as fruit-thinning agents for apples. Progress report. D. L. ABBOTT	1955	58
Growth substances as fruit-thinning agents for apples. Progress report. D. L. ABBOTT	1956	57
Fruit set on Cox's Orange Pippin in relation to spray programme. L. C. LUCKWILL	1956	61
Cover crops in relation to soil fertility and tree nutrition : II. An experiment with dessert bush apple trees. Progress report I. C. BOULD and R. M. JARRETT	1956	76
APPLE JUICE		
Factors affecting the quality and stability of concentrated fruit juices : I. Blackcurrant and apple concentrates. MARGARET E. KIESER, A. POLLARD, C. F. TIMBERLAKE and MARY R. MOSELEY	1953	189
ASCORBIC ACID		
The destruction of ascorbic acid by tissue preparations of cauliflower grown with different nitrogen and molybdenum supplies. E. J. HEWITT	1955	211
BANANAS		
Spray application problems : XXXV. The control of leaf-spot disease (<i>Mycosphaerella musicola</i>) on Lacatan bananas. The levels and distribution of Bordeaux mixture deposits. H. G. H. KEARNS and J. T. MARTIN	1956	135

BLACK CURRANTS

- A note on ten years' cropping of black currants at Long Ashton. E. W. HOBBS and E. CATLOW 1955 61
- Fruit drop in black currants: I. Factors affecting "running-off". S. S. TEAOTIA and L. C. LUCKWILL 1955 64
- Fruit drop in black currants: II. The effect of naphthalene acetic acid. L. C. LUCKWILL 1955 75
- Foliar analysis in relation to black currant nutrition: I. Investigations on leaf disc sampling. C. BOULD and E. G. BRADFELD 1955 93
- Fruit drop in black currants: III. The effect of 1-naphthalene acetic acid applied before harvest. L. C. LUCKWILL, MARGARET E. KIESER and A. POLLARD 1956 66
- The control of bindweed in black currants. L. C. LUCKWILL and A. I. CAMPBELL 1957 68

BLACK CURRANT JUICE AND SYRUP

- Factors affecting the quality and stability of concentrated fruit juices: I. Black currant and apple concentrates. MARGARET E. KIESER, A. POLLARD, C. F. TIMBERLAKE and MARY R. MOSELEY 1953 189
- The activity of pectin methylesterase in black currants. Progress report. MARGARET E. KIESER, A. POLLARD and D. J. SISSONS 1957 134

CARROTS

- The growth of carrots on an acid soil. W. PLANT 1954 203

CAULIFLOWER

- The destruction of ascorbic acid by tissue preparations of cauliflower grown with different nitrogen and molybdenum supplies. E. J. HEWITT 1955 211
- Factors affecting the activity of nitrate reductase in cauliflower plants. E. J. HEWITT, E. G. FISHER and M. I. CANDELA 1955 202

CHLOROSIS

- The use of iron chelates for the control of lime-induced chlorosis in fruit. Progress report I. C. BOULD 1953 91
- The use of iron chelates for the control of lime-induced chlorosis in fruit. Progress report II. C. BOULD 1955 87

CIDER, CHEMISTRY

- The composition of the juices of some varieties of cider apples. L. F. BURROUGHS and YVONNE P. MAY 1953 178
- The amino-acid content of cider in relation to the growth of lactic acid bacteria. L. F. BURROUGHS and J. G. CARR 1956 162

CIDER, FERMENTATION

- The role of nitrogen and vitamin B₁ in cider-making. L. F. BURROUGHS and A. POLLARD 1953 184
- Acid changes in cider fermentations: I. The significance of acid changes in cider-making. F. W. BEECH and A. POLLARD 1955 159
- Acid changes in cider fermentations: II. The effect of juice composition. J. G. CARR and G. C. WHITING 1955 163
- Acid changes in cider fermentations: III. The effect of sulphite treatments. F. W. BEECH, L. F. BURROUGHS and G. C. WHITING 1955 169
- Acid changes in cider fermentations: IV. Yeast autolysis and cider stability. L. F. BURROUGHS 1955 174
- The amino-acid content of cider in relation to the growth of lactic acid bacteria. L. F. BURROUGHS and J. G. CARR 1956 162

CIDER-MAKING, METHODS AND EQUIPMENT

- The production of bottled ciders free from deposit. F. W. BEECH 1954 179

CIDER, MICROBIOLOGY

- Problems of microbiological control in cider-making. F. W. BEECH and A. POLLARD 1953 171

	<i>Year</i>	<i>Page</i>
CIDER, ORCHARDING		
The production of cider fruit on bush trees : Observations on yields and orchard behaviour, 1950-53. Final report. R. R. WILLIAMS ..	1954	30
A revised list of recommended varieties of cider apples. ANON ..	1956	44
CIDER, POMOLOGY		
Pollination requirements of cider apple varieties : II. Progress report, 1954. R. R. WILLIAMS ..	1954	38
Stembuilders for cider trees : nursery trials. A. I. CAMPBELL ..	1955	46
Rootstocks and stembuilders for cider trees : nursery trial. A. I. CAMPBELL ..	1957	48
CIDER, VARIETIES AND VINTAGE TRIALS		
The composition of the juices of some varieties of cider apples. L. F. BURROUGHS and YVONNE P. MAY ..	1953	178
The production of cider fruit on bush trees. Vintage quality trials. Concluding report. L. F. BURROUGHS ..	1954	173
COVER CROPS		
Cover crops in relation to soil fertility and tree nutrition : II. An experiment with dessert bush apple trees. Progress report I. C. BOULD and R. M. JARRETT ..	1956	76
DEFICIENCY DISEASES (See Mineral Nutrition).		
DISEASES AND PESTS, APPLES		
Virus diseases of fruit trees : IV. Further observations on rubbery wood, chat-fruit and mosaic in apples. L. C. LUCKWILL ..	1953	40
The infection of apple stems through wounds caused by geese. E. W. HOBBS and R. W. MARSH ..	1953	89
Spray application problems : VIII. The control of apple and plum aphides by DDT and BHC spring washes. S. H. BENNETT ..	1953	129
Spray application problems : IX. Observations on the time of application and influence of site of deposition of BHC on the control of apple sawfly. (<i>Hoplocampa testudinea</i> Klug.). S. H. BENNETT ..	1953	135
Spray application problems : XII. Further field experiments on the control of apple scab by small-volume sprays. H. G. H. KEARNS, R. W. MARSH and N. G. MORGAN ..	1953	149
The role of eradicant fungicides in the control of apple canker : II. R. J. W. BYRDE and A. T. K. CORKE ..	1953	159
Observations on the sporulation of <i>Sclerotinia fructigena</i> on mummified apples and plums in late spring and summer. R. J. W. BYRDE ..	1953	163
Spraying experiments against apple and pear scab at Long Ashton, 1953. R. J. W. BYRDE, A. H. FIELDING and C. W. HARPER ..	1953	167
Spraying experiments against apple scab at Long Ashton, 1954. R. J. W. BYRDE, G. M. CLARKE and C. W. HARPER ..	1954	147
A summary of apple scab control experiments at Long Ashton, 1944-54. R. W. MARSH ..	1954	153
Spray application problems : XVIII. Observations on the application of chlorbenside for the control of the winter eggs of the Red Spider mite (<i>Metatetranychus ulmi</i> Koch). H. G. H. KEARNS, N. G. MORGAN and A. H. WILKINS ..	1954	131
The role of eradicant fungicides in the control of apple canker : III. A supplementary note. R. J. W. BYRDE and A. T. K. CORKE ..	1954	162
Bitter rot of apples : I. Branch inoculations with <i>Gloeosporium perennans</i> and <i>G. album</i> . A. T. K. CORKE ..	1954	164
Virus diseases of fruit trees : V. Experiments on rubbery wood, mosaic and flat limb of apples. L. C. LUCKWILL ..	1955	51
An unusual attack on apples by a sawfly (<i>Ametastegia</i> sp.). S. H. BENNETT ..	1955	120
Spray application problems : XXV. The application of chlorbenside and chlorfensone for the control of the winter eggs of the Red Spider mite (<i>Metatetranychus ulmi</i> Koch). H. G. H. KEARNS, N. G. MORGAN and A. H. WILKINS ..	1955	125
Spray application problems : XXVII. Field experiments in the control of apple and pear scab by small-volume sprays, 1955. H. G. H. KEARNS, R. W. MARSH and N. G. MORGAN ..	1955	136

DISEASES AND PESTS, APPLES (*contd.*)

Spraying experiments against apple scab at Long Ashton, 1955. R. J. W. BYRDE, G. M. CLARKE and C. W. HARPER	1955	140
Spraying experiments against apple scab at Long Ashton, 1956. R. J. W. BYRDE, G. M. CLARKE and C. W. HARPER	1956	103
Spraying trials at Long Ashton, 1953-56, for the control of <i>Gloeosporium</i> storage rot in Allington Pippins. R. W. MARSH and K. L. EDNEY ..	1956	109
Spraying experiments against apple scab at Long Ashton, 1957. R. J. W. BYRDE, G. M. CLARKE and C. W. HARPER	1957	93
A preliminary comparison of the temperature-germination relationships of ascospores and of conidia of the apple and pear scab fungi (<i>Venturia inaequalis</i> and <i>V. pirina</i>). D. WHEATLEY	1957	97
Observations on the mode of perennation of apple mildew. R. T. BURCHILL	1957	114
The reduction of orchard sources of <i>Gloeosporium</i> disease. R. O. SHARPLES	1957	105
Virus diseases of fruit trees: VI. Graft transmission of chat fruit. L. C. LUCKWILL	1957	56

DISEASES AND PESTS, BLACK CURRANTS

Black currant leaf spot: I. Studies on perennation and infection. A. T. K. CORKE	1953	154
Sources of variability in sampling black currants for leaf spot. G. M. CLARKE and A. T. K. CORKE	1954	199
A rapid method of assessing black currant leaf spot. G. M. CLARKE and A. T. K. CORKE	1955	196
Black currant leaf spot: a note on further laboratory tests of fungicides on overwintered leaves. A. T. K. CORKE	1956	120

DISEASES AND PESTS, PEARS

Spraying experiments against apple and pear scab at Long Ashton, 1953. R. J. W. BYRDE, A. H. FIELDING and C. W. HARPER	1953	167
Spray application problems: XXVII. Field experiments in the control of apple and pear scab by small-volume sprays, 1955. H. G. H. KEARNS, R. W. MARSH and N. G. MORGAN	1955	136
A preliminary comparison of the temperature-germination relationships of ascospores and of conidia of the apple and pear scab fungi (<i>Venturia inaequalis</i> and <i>V. pirina</i>). D. WHEATLEY	1957	97

DISEASES AND PESTS, PLUMS

Spray application problems: VIII. The control of apple and plum aphides by DDT and BHC spring washes. S. H. BENNETT	1953	129
Observations on the sporulation of <i>Sclerotinia fructigena</i> on mummified apples and plums in late spring and summer. R. J. W. BYRDE	1953	163

DISEASES AND PESTS, POTATOES

Small-volume air-flow spraying for the control of potato blight. H. G. H. KEARNS and N. G. MORGAN	1954	169
---	------	-----

DOMESTIC FOOD PRESERVATION

(See Preserving).

ENZYMES

Factors affecting the activity of nitrate reductase in cauliflower plants. E. J. HEWITT, E. G. FISHER and M. I. CANDELA	1955	202
Some observations on the effects of fungicides on enzyme systems in <i>Botrytis cinerea</i> . E. C. HISLOP	1956	116
The activity of pectin methylesterase in black currants. Progress report. MARGARET E. KIESER, A. POLLARD and D. J. SISSONS	1957	134

FERTILIZERS

(See Manures and Manuring).

FRUIT JUICES

Factors affecting the quality and stability of concentrated fruit juices: I. Black currant and apple concentrates. MARGARET E. KIESER, A. POLLARD, C. F. TIMBERLAKE and MARY R. MOSELEY	1953	189
---	------	-----

	Year	Page
FUNGICIDES		
(See also Analytical Methods).		
The effect of chemical structure on biological activity : the significance of chlorine in certain insecticides, fungicides, and plant growth-regulators. D. WOODCOCK	1953	96
The fungicidal properties of coal-tar distillates. Progress report. G. V. COLES and R. J. W. BYRDE	1953	109
The role of eradicant fungicides in the control of apple canker : II. R. J. W. BYRDE and A. T. K. CORKE	1953	159
The fungicidal properties of coal-tar distillates. Progress report II. G. V. COLES, J. T. MARTIN and R. J. W. BYRDE	1954	74
Spray application problems : XIV. Laboratory and field experiments with Burgundy mixtures. E. SOMERS	1954	90
The role of eradicant fungicides in the control of apple canker : III. A supplementary note. R. J. W. BYRDE and A. T. K. CORKE	1954	162
The role of supplements in copper fungicide sprays. E. SOMERS	1955	111
Spray application problems : XXVI. The range of fungicidal action of micro-deposits of captan on artificial surfaces and on leaves. D. J. BUTT	1955	127
The fungistatic properties of coal-tar constituents. G. V. COLES, J. T. MARTIN and R. J. W. BYRDE	1956	101
Some observations on the effects of fungicides on enzyme systems in <i>Botrytis cinerea</i> . E. C. HISLOP	1956	116
Black currant leaf spot. A note on further laboratory tests of fungicides on overwintered leaves. A. T. K. CORKE	1956	120
Spray application problems : XLIII. Note on the preparation of Bordeaux mixture. E. SOMERS	1957	82
Preliminary tests of potential orchard fungicides. R. J. W. BYRDE and NORA M. WAUGH	1957	89
GLOEOSPORIUM spp. ON APPLE		
(See Diseases and Pests, Apple, and Storage, Fruit).		
GOOSEBERRIES		
The propagation of gooseberries : I. Some factors influencing the rooting of hardwood cuttings. BARBARA A. RAKE	1953	79
The propagation of gooseberries : II. The influence of basal wounding and size of shoot on the rooting of hardwood cuttings. BARBARA A. RAKE	1954	63
The propagation of gooseberries : III. The effect of time of taking and planting hardwood cuttings and the influence of buds on rooting. BARBARA A. RAKE	1955	78
The propagation of gooseberries : IV. Softwood cuttings. BARBARA A. RAKE	1956	70
The propagation of gooseberries : V. Layering. BARBARA A. RAKE	1956	72
The propagation of gooseberries : VI. The influence of source on the rooting of hardwood cuttings. BARBARA A. RAKE	1957	59
The classification of gooseberries : I. Useful characters for the classification and identification of varieties. BARBARA A. RAKE	1957	60
GRASS		
(See Cover Crops).		
GROWTH PROMOTING SUBSTANCES AND GROWTH INHIBITING SUBSTANCES		
2:4:5-TP as a fruit-ripening agent : I. Apple <i>var.</i> Worcester Pearmain. D. L. ABBOTT	1953	53
Growth substances as fruit-thinning agents for apples. Progress report. D. L. ABBOTT	1953	58
The effect of chemical structure on biological activity : the significance of chlorine in certain insecticides, fungicides and plant growth-regulators. D. WOODCOCK	1953	96
2:4:5-TP as a fruit-ripening agent : II. Apple <i>var.</i> Worcester Pearmain. D. L. ABBOTT	1954	47
Growth substances as fruit-thinning agents for apples. Progress report. D. L. ABBOTT	1955	58
Fruit drop in black currants : II. The effect of naphthalene acetic acid. L. C. LUCKWILL	1955	75

	Year	Page
GROWTH PROMOTING SUBSTANCES AND GROWTH INHIBITING SUBSTANCES (<i>contd.</i>)		
Growth substances as fruit-thinning agents for apples. Progress report.		
D. L. ABBOTT	1956	57
Fruit drop in black currants : III. The effect of 1-naphthalene acetic acid applied before harvest. L. C. LUCKWILL, MARGARET E. KIESER and A. POLLARD	1956	66
The control of bindweed in black currants. L. C. LUCKWILL and A. I. CAMPBELL	1957	68
INSECTICIDES		
(<i>See also</i> Analytical Methods).		
The effect of chemical structure on biological activity : the significance of chlorine in certain insecticides, fungicides and plant growth-regulators. D. WOODCOCK	1953	96
Spray application problems : XI. A note on the preparation of a combined DDT- <i>gamma</i> BHC emulsion of high wetting properties as a substitute for winter washes. H. G. H. KEARNS and N. G. MORGAN	1953	146
Spray application problems : XVIII. Observations on the application of chlorbenside for the control of the winter eggs of the Red Spider mite (<i>Metatetranychus ulmi</i> Koch). H. G. H. KEARNS, N. G. MORGAN and A. H. WILKINS	1954	131
Spray application problems : XXV. The application of chlorbenside and chlorfensone for the control of the winter eggs of the Red Spider mite (<i>Metatetranychus ulmi</i> Koch). H. G. H. KEARNS, N. G. MORGAN and A. H. WILKINS	1955	125
Spray application problems : XXXVI. Benzene, toluene and naphtha formulations of spray washes. H. R. MAPOTHER and R. F. BATT	1956	141
IRON		
The use of iron chelates for the control of lime-induced chlorosis in fruit. Progress report I. C. BOULD	1953	91
The use of iron chelates for the control of lime-induced chlorosis in fruit. Progress report II. C. BOULD	1955	87
JUBILEE CELEBRATIONS		
Jubilee celebrations. M. GREENWOOD	1953	29
LOGANBERRIES		
Leaf-bud propagation of a virus-tested loganberry clone. E. W. HOBBS and A. I. CAMPBELL	1957	65
MACHINERY, SPRAYING		
(<i>See</i> Sprays and Spraying).		
MANURES AND MANURING		
Manurial experiments with fruit : I. The effect of treatments on soil fertility and on the growth, yield and leaf nutrient status of strawberry, <i>var.</i> Royal Sovereign. C. BOULD and E. CATLOW	1956	84
MATURITY OF FRUIT		
2:4:5-TP as a fruit-ripening agent : I. Apple <i>var.</i> Worcester Pearmain. D. L. ABBOTT	1953	53
2:4:5-TP as a fruit ripening agent : II. Apple <i>var.</i> Worcester Pearmain. D. L. ABBOTT	1954	47
METEOROLOGY		
Meteorological records, 1953. G. E. CLOTHIER	1953	208
Meteorological records, 1954. G. E. CLOTHIER	1954	202
Meteorological records, 1955. G. E. CLOTHIER	1955	201
Meteorological records, 1956. G. E. CLOTHIER	1956	176
Meteorological records, 1957. G. E. CLOTHIER	1957	156
MINERAL NUTRITION		
The use of iron chelates for the control of lime-induced chlorosis in fruit. Progress report I. C. BOULD	1953	91

	<i>Year</i>	<i>Page</i>
MINERAL NUTRITION (<i>contd.</i>)		
The molybdenum requirements of tomato plants given different types of nitrogen supply in sand culture. E. J. HEWITT and C. C. MCCREADY	1953	209
A failure in apple trees on a strongly acid soil. C. BOULD and E. G. BRADFIELD	1954	69
The growth of carrots on an acid soil. W. PLANT	1954	203
The use of iron chelates for the control of lime-induced chlorosis in fruit. Progress report II. C. BOULD	1955	87
Foliar analysis in relation to black currant nutrition : I. Investigations on leaf disc sampling. C. BOULD and E. G. BRADFIELD	1955	93
Factors affecting the activity of nitrate reductase in cauliflower plants. E. J. HEWITT, E. G. FISHER and M. I. CANDELA	1955	202
The destruction of ascorbic acid by tissue preparations of cauliflower grown with different nitrogen and molybdenum supplies. E. J. HEWITT	1955	211
Cover crops in relation to soil fertility and tree nutrition : II. An experiment with dessert bush apple trees. Progress report I. C. BOULD and R. M. JARRETT	1956	76
Manurial experiments with fruit : I. The effect of treatments on soil fertility and on the growth, yield and leaf nutrient status of strawberry, <i>var.</i> Royal Sovereign. C. BOULD and E. CATLOW	1956	84
MOLYBDENUM		
The molybdenum requirements of tomato plants given different types of nitrogen supply in sand culture. E. J. HEWITT and C. C. MCCREADY	1953	209
The destruction of ascorbic acid by tissue preparations of cauliflower grown with different nitrogen and molybdenum supplies. E. J. HEWITT	1955	211
PEARS		
(<i>See Diseases and Pests, Pears. See also under Perry.</i>)		
Rosetting and incompatibility of pears on Quince A. Progress report I. R. R. WILLIAMS and A. I. CAMPBELL	1956	51
Male sterility in Bristol Cross pear. D. WILSON	1957	52
PECTIN		
The activity of pectin methylesterase in black currants. Progress report. MARGARET E. KIESER, A. POLLARD and D. J. SISSONS	1957	134
PERRY PEARS		
A survey of perry pears in the West Midlands : I. North-west Gloucestershire. R. R. WILLIAMS	1953	64
Perry pears and their characters : I. R. R. WILLIAMS	1953	70
Perry pears and their characters : II. R. R. WILLIAMS	1954	52
Perry pears for planting. R. R. WILLIAMS	1956	48
Rosetting and incompatibility of pears on Quince A. Progress report I. R. R. WILLIAMS and A. I. CAMPBELL	1956	51
PESTS AND DISEASES		
(<i>See Diseases and Pests.</i>)		
PLANT WAXES		
Studies on the natural protective covering of plants : I. Plant wax in relation to resistance to infection by fungi. J. T. MARTIN	1956	94
Studies on the natural protective covering of plants : II. The wax and cutin of leaves and fruits. J. T. MARTIN, R. F. BATT and MARGARET F. ROBERTS	1957	84
PLUMS		
(<i>See Diseases and Pests, Plums.</i>)		
Rootstocks suitable for some new plum varieties raised at Long Ashton : nursery trials. A. I. CAMPBELL	1954	60
POLLEN AND POLLINATION		
Pollination requirements of cider apple varieties : II. Progress report, 1954. R. R. WILLIAMS	1954	38
Male sterility in Bristol Cross pear. D. WILSON	1957	52

POTATOES

(See Diseases and Pests, Potatoes).

PRESERVING

A comparison of some varieties of fruit preserved by bottling and by freezing. Progress report IV. ALICE CRANG and MARGARET STURDY	1953	199
Notes on domestic meat and poultry preservation. ALICE CRANG	1953	206
A comparison of some varieties of vegetables preserved by canning and by freezing. Progress report III. ALICE CRANG and MARGARET STURDY	1954	187
A comparison of some varieties of fruit preserved by bottling and by freezing. Progress report V. ALICE CRANG and MARGARET STURDY	1954	192
A comparison of some varieties of vegetables preserved by canning and by freezing. Progress report IV. ALICE CRANG and MARGARET STURDY	1955	178
A comparison of some varieties of fruit preserved by bottling and by freezing. Progress report VI. ALICE CRANG and MARGARET STURDY	1955	182
Domestic freezing of pork and pork products. MARGARET STURDY and ALICE CRANG	1955	188
A comparison of some varieties of vegetables preserved by canning and by freezing. Progress report V. ALICE CRANG and MARGARET STURDY	1956	167
A comparison of some varieties of fruit preserved by bottling and by freezing. Progress report VII. ALICE CRANG and MARGARET STURDY	1956	170
Storage of frozen bacon, brawn and venison. MARGARET STURDY and ALICE CRANG	1957	137

RADIOACTIVE ISOTOPES

Application of the radioactive tracer technique to problems in plant nutrition and crop protection. W. D. E. THOMAS	1953	102
Radioactive tracer studies during the period 1953-55. C. P. LLOYD-JONES	1955	116

RED SPIDER

Spray application problems: XVIII. Observations on the application of chlorbenside for the control of the winter eggs of the Red Spider mite (<i>Metatetranychus ulmi</i> Koch). H. G. H. KEARNS, N. G. MORGAN and A. H. WILKINS	1954	131
Spray application problems: XXV. The application of chlorbenside and chlorfensone for the control of the winter eggs of the Red Spider mite (<i>Metatetranychus ulmi</i> Koch). H. G. H. KEARNS, N. G. MORGAN and A. H. WILKINS	1955	125

ROOTSTOCKS

The use of apomictic seedling rootstocks for apples. Progress report. L. C. LUCKWILL and A. I. CAMPBELL	1953	47
Rootstocks suitable for some new plum varieties raised at Long Ashton: nursery trials. A. I. CAMPBELL	1954	60
Rosetting and incompatibility of pears on Quince A. Progress report I. R. R. WILLIAMS and A. I. CAMPBELL	1956	51
Rootstocks and stembuilders for cider trees: nursery trial. A. I. CAMPBELL	1957	48

SOIL CONDITIONERS

Soil conditioners. II. The effect of HPAN and VAMA on the yield of strawberries. C. BOULD	1957	71
---	------	----

SPRAYS AND SPRAYING

The fungicidal properties of coal-tar distillates. G. V. COLES and R. J. W. BYRDE	1953	109
Spray Application Problems:		
VII. The determination of DDT in plant materials. J. T. MARTIN and R. F. BATT	1953	121
VIII. The control of apple and plum aphides by DDT and BHC spring washes. S. H. BENNETT	1953	129
IX. Observations on the time of application and influence of site of deposition of BHC on the control of apple sawfly (<i>Hoplocampa testudinea</i> Klug.) S. H. BENNETT	1953	135

SPRAYS AND SPRAYING (*contd.*)

Year Page

X. The effects of spraying techniques on the control of some fruit insects. Lance and air-flow mist spraying. H. G. H. KEARNS and N. G. MORGAN	1953	139
XI. A note on the preparation of a combined DDT- <i>gamma</i> BHC emulsion of high wetting properties as a substitute for winter washes. H. G. H. KEARNS and N. G. MORGAN	1953	146
XII. Further field experiments on the control of apple scab by small-volume sprays. H. G. H. KEARNS, R. W. MARSH and N. G. MORGAN	1953	149
Spraying experiments against apple and pear scab at Long Ashton, 1953. R. J. W. BYRDE, A. H. FIELDING and C. W. HARPER	1953	167
Spray Application Problems :		
XIII. Determination of captan deposits. Progress report. J. T. MARTIN and J. A. PICKARD	1954	83
XIV. Laboratory and field experiments with Burgundy mixtures. E. SOMERS	1954	90
XV. Copper and DDT deposits from large and small-volume application. N. G. MORGAN and J. T. MARTIN	1954	97
XVI. The evaluation of an average droplet diameter in sprays. C. G. L. FURMIDGE	1954	106
XVII. The measurement of spray droplet size in the field. C. G. L. FURMIDGE	1954	118
XVIII. Observations on the application of chlorbenside for the control of the winter eggs of the Red Spider mite (<i>Metatetranychus ulmi</i> Koch). H. G. H. KEARNS, N. G. MORGAN and A. H. WILKINS	1954	131
XIX. Further field experiments on the control of apple scab by small-volume sprays. H. G. H. KEARNS, R. W. MARSH and N. G. MORGAN	1954	134
XX. Light-weight small power sprayers (34 and 70 c.c. I.C. engines). H. G. H. KEARNS and N. G. MORGAN	1954	138
Spraying experiments against apple scab at Long Ashton, 1954. R. J. W. BYRDE, G. M. CLARKE and C. W. HARPER	1954	147
A summary of apple scab control experiments at Long Ashton, 1944-54. R. W. MARSH	1954	153
Small-volume air-flow spraying for the control of potato blight. H. G. H. KEARNS and N. G. MORGAN	1954	169
The role of supplements in copper fungicide sprays. E. SOMERS	1955	111
Spraying experiments against apple scab at Long Ashton, 1955. R. J. W. BYRDE, G. M. CLARKE and C. W. HARPER	1955	140
Spray Application Problems :		
XXI. The rapid assessment of deposits of copper fungicides. J. T. MARTIN	1955	98
XXII. Determination of captan deposits : II. J. T. MARTIN and J. A. PICKARD	1955	103
XXIII. Determination of deposits of DDT, <i>gamma</i> -BHC and chlorbenside. J. T. MARTIN and R. F. BATT	1955	106
XXIV. The study of plant surfaces and spray deposits by means of transparent impressions. S. H. BENNETT and C. G. L. FURMIDGE	1955	121
XXV. The application of chlorbenside and chlorfensone for the control of the winter eggs of the Red Spider mite (<i>Metatetranychus ulmi</i> Koch). H. G. H. KEARNS, N. G. MORGAN and A. H. WILKINS	1955	125
XXVI. The range of fungicidal action of micro-deposits of captan on artificial surfaces and on leaves. D. J. BUTT	1955	127
XXVII. Field experiments in the control of apple and pear scab by small-volume sprays, 1955. H. G. H. KEARNS, R. W. MARSH and N. G. MORGAN	1955	136
XXVIII. A compressed air spray nozzle for laboratory and field equipment for small-volume air-flow spraying. H. G. H. KEARNS and N. G. MORGAN	1955	146
XXIX. A tractor-driven air-flow mist-blower for experimental work. H. G. H. KEARNS and N. G. MORGAN	1955	151
XXX. Mobile observation platforms for the examination of tree crops. H. G. H. KEARNS and N. G. MORGAN	1955	156
Fruit set on Cox's Orange Pippin in relation to spray programme. L. C. LUCKWILL	1956	61
Spraying experiments against apple scab at Long Ashton, 1956. R. J. W. BYRDE, G. M. CLARKE and C. W. HARPER	1956	103

SPRAYS AND SPRAYING (*contd.*)

Spraying trials at Long Ashton, 1953-56, for the control of <i>Gloeosporium</i> storage rot in Allington Pippins. R. W. MARSH and K. L. EDNEY	1956	109
Spray Application Problems :		
XXXI. The determination of sulphur deposits on foliage. V. D. KRENTOS, R. F. BATT and J. T. MARTIN	1956	122
XXXII. Note on the determination of surface deposits of copper fungicides. J. T. MARTIN	1956	125
XXXIII. The micro-determination of DDT. R. F. BATT and J. T. MARTIN	1956	127
XXXIV. The determination of spray deposits of chlorobenzilate. E. J. SKERRETT and E. A. BAKER	1956	130
XXXV. The control of leaf-spot disease (<i>Mycosphaerella musicola</i>) on Lacatan bananas. The levels and distribution of Bordeaux mixture deposits. H. G. H. KEARNS and J. T. MARTIN	1956	135
XXXVI. Benzene, toluene and naphtha formulations of spray washes. H. R. MAPOTHER and R. F. BATT	1956	141
XXXVII. A disc punch for sampling leaves for the assay of spray deposits. H. G. H. KEARNS and N. G. MORGAN	1956	145
XXXVIII. A centrifugal spray pump (with an 80 c.c. 2-stroke engine). H. G. H. KEARNS and N. G. MORGAN	1956	147
XXXIX. A general-purpose lance for use with power spray machinery on tropical crops. H. G. H. KEARNS and N. G. MORGAN	1956	151
XL. A light-weight spray lance. H. G. H. KEARNS and N. G. MORGAN	1956	153
XLI. Modifications of the Long Ashton $\frac{1}{4}$ " B.S.P. spray nozzle for special requirements. H. G. H. KEARNS and N. G. MORGAN	1956	157
Spraying experiments against apple scab at Long Ashton, 1957. R. J. W. BYRDE, G. M. CLARKE and C. W. HARPER	1957	93
Spray Application Problems :		
XLII. Mercury deposits on apple fruits and foliage. J. T. MARTIN and J. A. PICKARD	1957	76
XLIII. Note on the preparation of Bordeaux mixture. E. SOMERS	1957	82
XLIV. A compressed air nozzle for small-volume spraying. T. E. COBBALD	1957	123
XLV. The performance of a power knapsack mist sprayer. T. E. COBBALD	1957	127

STATISTICS

Sources of variability in sampling black currants for leaf spot. G. M. CLARKE and A. T. K. CORKE	1954	199
A rapid method of assessing black currant leaf spot. G. M. CLARKE and A. T. K. CORKE	1955	196

STORAGE (FRUIT)

Spraying trials at Long Ashton, 1953-56, for the control of <i>Gloeosporium</i> storage rot in Allington Pippins. R. W. MARSH and K. L. EDNEY	1956	109
---	------	-----

STOCKS

(See under Rootstocks)

STRAWBERRIES

Manurial experiments with fruit : I. The effect of treatments on soil fertility and on the growth, yield and leaf nutrient status of strawberry, <i>var.</i> Royal Sovereign. C. BOULD and E. CATLOW	1956	84
Soil conditioners : II. The effect of HPAN and VAMA on the yield of strawberries. C. BOULD	1957	71

TAR DISTILLATES

(See Fungicides)

THINNING, BLOSSOM AND FRUIT

Growth substances as fruit-thinning agents for apples. Progress report. D. L. ABBOTT	1953	58
Growth substances as fruit-thinning agents for apples. Progress report. D. L. ABBOTT	1955	58
Growth substances as fruit-thinning agents for apples. Progress report. D. L. ABBOTT	1956	57

TOMATOES

- The molybdenum requirements of tomato plants given different types
of nitrogen supply in sand culture. E. J. HEWITT and C. C.
MCREADY 1953 209

VIRUS DISEASES

- Virus diseases of fruit trees : IV. Further observations on rubbery wood,
chat-fruit and mosaic in apples. L. C. LUCKWILL 1953 40
Virus diseases of fruit trees : V. Experiments on rubbery wood, mosaic
and flat limb of apples. L. C. LUCKWILL 1955 51
Virus diseases of fruit trees : VI. Graft transmission of chat-fruit.
L. C. LUCKWILL 1957 56

WEEDS

- The control of bindweed in black currants. L. C. LUCKWILL and A. I.
CAMPBELL 1957 68

WILLOWS

- Cricket bat willows : sale and utilization of the Long Ashton trees.
K. G. STOTT 1957 143

THE JOURNAL OF HORTICULTURAL SCIENCE

The Journal of Horticultural Science, which is sponsored by the Long Ashton Research Station and the East Malling Research Station, welcomes contributions on horticultural science from Research Institutes at home and abroad. Papers for publication and all communications should be sent to the Editor at East Malling Research Station, Maidstone, Kent.

The current Volume 33 (1958) contains papers from both the sponsor Research Stations, from the John Innes Horticultural Institution, National Vegetable Research Station, Glasshouse Crops Research Institute, Ditton Laboratory, Wye College and the Grassland Research Institute. There are also papers from Australia, the United States and the Netherlands. The list of subjects is again a wide one and includes an account of the first ten years' behaviour of dessert apples under different systems of planting and of a trial of post-blossom fungicides on one of the plantations. Other subjects pertaining to fruit research are rootstocks, compatibility, the effect of radio-active phosphorus on stock/scion relationships, and also its uptake and distribution in relation to the mutation rate in plants; parthenocarp in apples and pears, root development in apples and black currants; studies of soil uniformity following the removal of mature apple trees and of the effect of meteorological conditions on cropping of Sturmer apples. There are papers on raspberry viruses, inactivation of strawberry viruses by heat treatment, quince indicators for pear viruses and on loganberry cane spot. The Volume contains several papers on vegetable research, both in the open and under glass, notably on tomatoes and in relation to soil moisture. The assessment of yield of canning peas is discussed; a device for the automatic control of day-length is described.

The Journal is issued in quarterly parts and is published by Messrs. Headley Brothers, 109 Kingsway, London, W.C.2., to whom intending subscribers should apply. The subscription rates for the current volume are 60 shillings per volume (rate for Canada and the U.S.A., \$8.50) or 20 shillings for a single number. Back numbers of several Volumes are available from the publishers.

